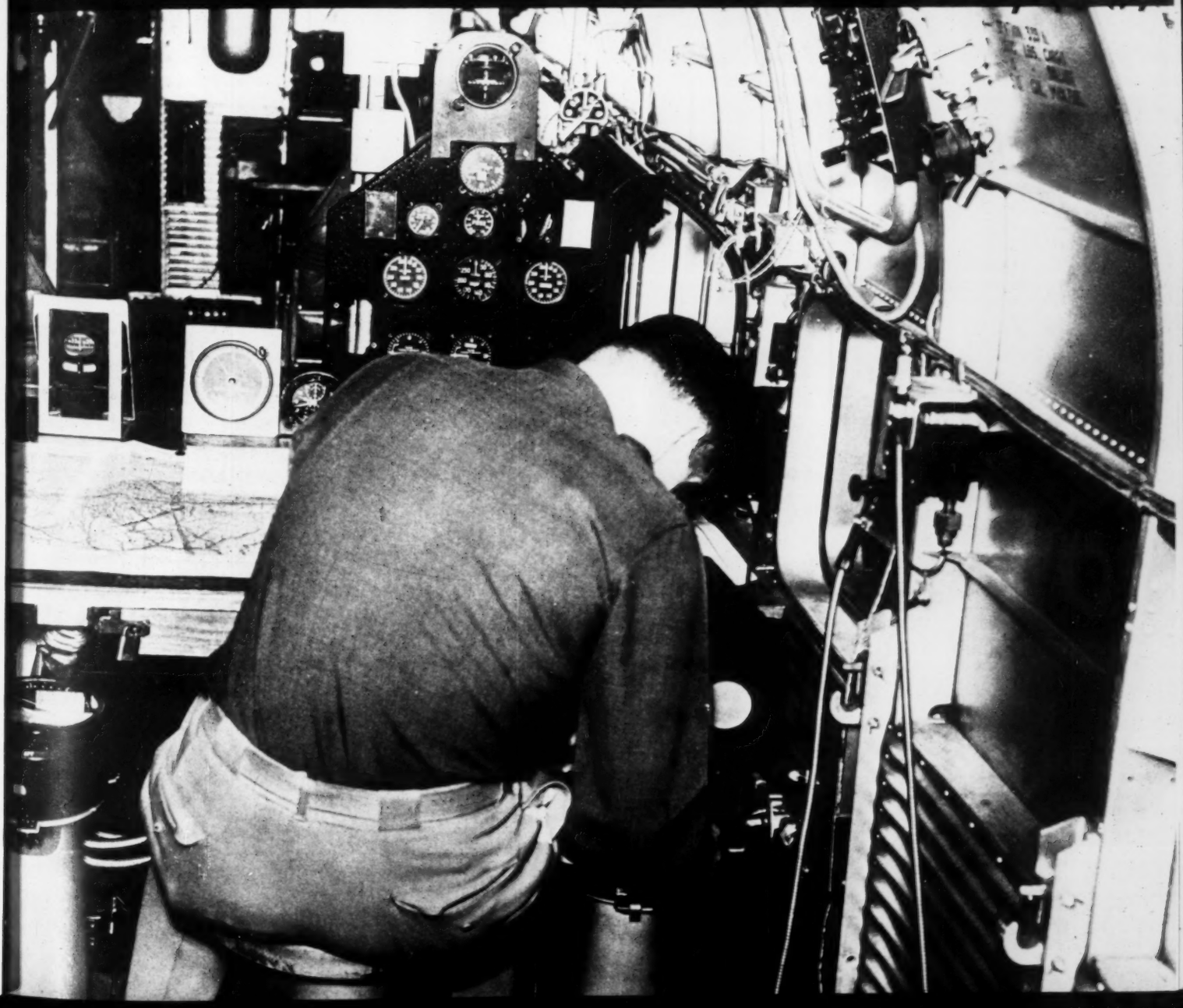
Instruments

THE MAGAZINE OF

Measurement and Control

Vol. 15
APRIL
1942
No. 4



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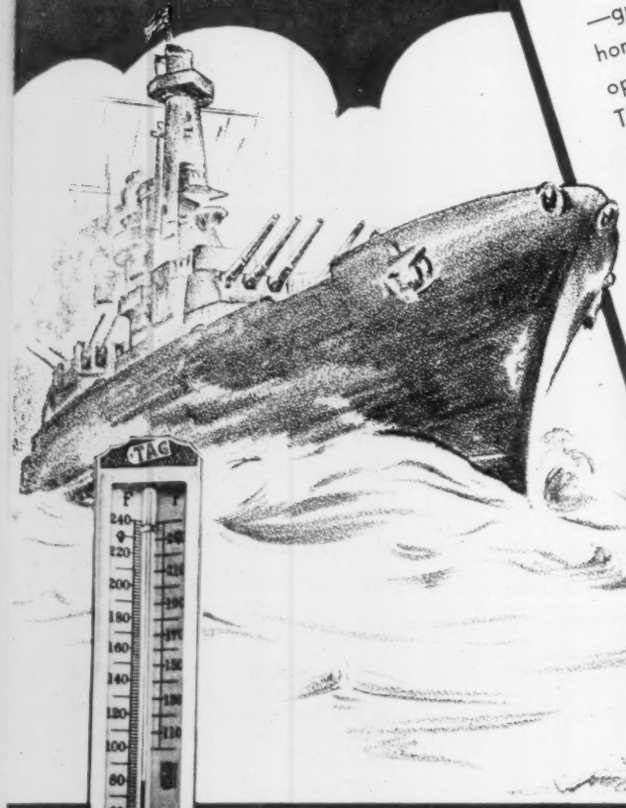
TAG Instruments Control Conditions that Affect War Industry Production and Guard Front Line Performance

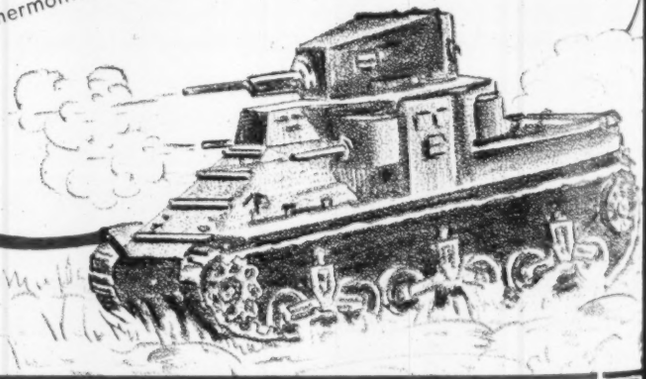
On scores of production lines, the implements of America's rising military might roll out in ever-increasing tempo . . . On every fighting front, the certainty of standardized quality keeps 'em rolling, sailing and flying!

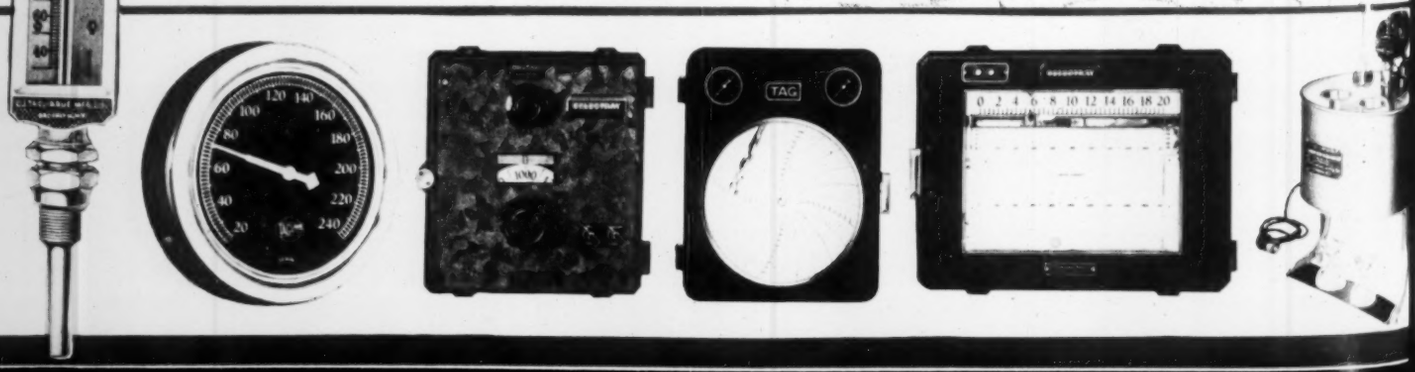
TAG Instruments are recording and controlling manufacturing conditions —guarding against waste and stepping up production on the industrial home front. In the field—tanks, ships, 'planes and motorized equipment operate more effectively because of high standard fuels and lubricants. TAG Oil Testing Instruments in hundreds of laboratories aid in determining and holding these vital standards.

Tie in your war production efforts with TAG . . . save time . . . nip rejects and, above all, step up the pace of production. If you are confronted with a production problem, bring it to us. We have some of the answers and are eager to serve you.

A few of the TAG Instruments now in service in America's War Production efforts are illustrated below, as well as those in action on the fighting fronts. Write for complete information on TAG Indicating, Recording and Controlling Instruments for the plant, and TAG Oil Testing Instruments, Chemical Thermometers and Hydrometers for the laboratory.







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Park & Nostrand Ave's., Brooklyn, N. Y.

Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

LAST October the first Special Aviation Issue of *Instruments* was published. It was a success in every way. Not only did most regular subscribers in aviation work order extra copies for their friends, but many men who had never seen the magazine before ordered copies for *their* friends. That October issue "sold" more than a thousand new subscriptions—which probably means four or five thousand new readers because most people who "discover" *Instruments* pass it around to call attention to articles of special interest.

It is reasonable to expect that this second Aviation Issue, likewise, will be the first issue of *Instruments* to be read by several thousand new readers. If you are one of them I bid you welcome to the ranks of a sort of brotherhood:

"We are all colleagues in one esteemed profession. All men who invent, design, build, sell, specify, apply, install, service and maintain measuring instruments; meters and automatic control equipment belong to one fraternity that strives to . . . eliminate human drudgery."

These words appeared on this editorial page in June 1933 and met with acceptance, so I hail you as a brother.

This brotherhood which you have joined has a watchword. "What is it that unites us? Meters and gages? No: more than instruments — Instrumentation." These words, too, met with acceptance, so it may be explained that instrumentation (with a small i) refers to the things,

[Examples: the navigational instruments of an airplane, taken together; or the plane's power-plant instruments; or *all* the instruments on a plane; or the array of gages, meters and controllers making up a boiler control panel; in short, a coördinated set of measurement and control devices],

while Instrumentation (with a capital I) refers to the science

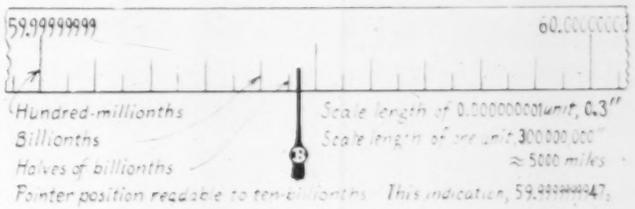
[the body of knowledge formulated and arranged in a rational system by The Instrumentation Manual Project—a perpetual project started eighteen years ago and destined to go on as long as mankind strives to do its work better and better].

We're all eager acolytes at the altar of this science, for it is an inexhaustible source of a rich mixture of fascination and practical bread-and-butter utility. Though infinite in its details, it nevertheless has been boiled down to four fundamental doctrines:

(1) Eliminate the variables by reducing them to measurables;
(2) Whatever is to be controlled should first be measured;
(3) If you can measure it you can control its effects;
(4) If you control by hand you should control automatically.

Having read this far, you probably are getting the "feel" of instrumentation and Instrumentation. Or you will be getting it as you read *Instruments*. Or, for all I know, you had it before and that's why you became a reader. At any rate, you surely know by now, if you didn't before, that there's a fraternity vernacular. It is called the Terminology of Instrumentation. Like the science itself, it is in process: it never will be finished. As with the science, a beginning has been made toward definitive meanings. This is especially true of such words as "precision," "sensitivity" and "accuracy." I shan't bore you with formal definitions. I only want to tell you that some of your fellow-members are those Priests of Precision whose feats you read about. Not only at the National Bureau of Standards do they perform miracles of fine measurements, but in industrial research.

For example, at the Bell Telephone Laboratories they check their frequency standards to one part in ten billion. (No, not ten million but ten billion.) The apparatus does not give direct readings; but let's imagine a direct-reading frequency meter with a scale covering five cycles (57.5 to 62.5 with 60 at mid-scale) and easily readable to ten-billionths of one cycle. Simple arithmetic yields the specifications. A portion of that scale is pictured here—not *all* of it, for its total length is the length of the Equator!



Is the sensitivity on a par with this degree of precision? Yes, for that's the way the Bell Labs instrumenticians check deviations in comparing one standard with another.

Is the accuracy comparable? Not by a long shot! Why not? Because the world's ultimate standards of reference, which indicate absolute values and not merely deviations, are accurate to "only" one part in millions and not billions. At that, a five-cycle scale readable to a ten-millionth of a cycle would be about twenty-five miles long. No wonder electric clocks plugged into a.c. from large utilities keep "perfect" time: when a condition can be measured to 0.00001% in the laboratory, an industrial automatic controller can hold that condition on the nose. "No controller can be better than its primary element" and the better the measurement, the closer the possible control.

No doubt, you are thinking of applying this principle in helping win the war by improving some automatic-control job you know of. Brother, if that's the way your mind works, you're an Instrumentician now!

No doubt, one reason why you've become a reader is a purely patriotic reason. Well, I was preaching Preparedness on this page when some other tech mag editors were saying we should "do business with Hitler." Back in 1933 I warned against "the Nazi plan of abolishing Christianity." This page has been, is and will continue to be dedicated to *help you help win the war!*

—MFB

Aviation Instrumentation Department.—Plans are under way for the inauguration of a regular monthly department dealing with all aspects of aviation instrumentation. It probably will start in the June issue.

Instruments Publishing Co.'s First Service Star.—The many friends of William Scoltock, who combined the duties of office assistant and outside representative, will be proud to know that he enlisted in the U. S. Maritime Service.

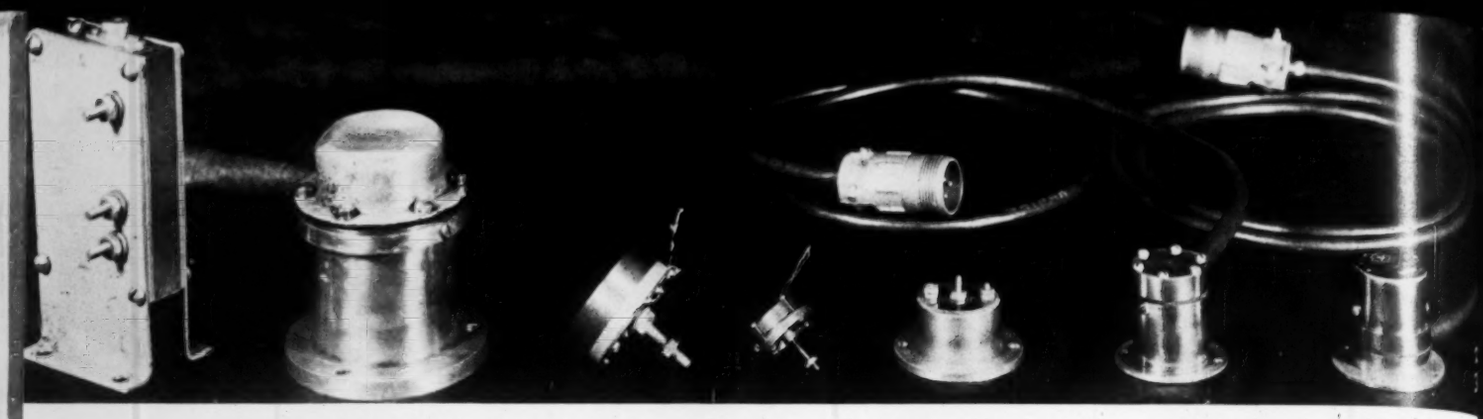


Fig. 1. Evolution of the Glenn L. Martin Accelerometer Type Pickup. *Left*—old carbon-pile type; *right*—latest variable-reactance type.

Measuring the Elastic Airplane

By WELCOME W. BENDER, JR.
Vibration Engineer, The Glenn L. Martin Co., Baltimore, Md.

WITH the development in recent years of large high-performance airplanes, the structural engineer has had to give increased attention to the problems of elastic deflections of the airplane, rather than to designs which are investigated for strength alone. But he has now become well aware that the physics of structures which are considered elastic, rather than rigid bodies, encompasses the broad field of vibrations and a dozen related specialized lines of study, which are all in one way or another connected with the dynamic performance of the airplane.

The concepts of applied loads, gust accelerations, landing shock loads, induced vibrations due to engines, propellers, cannon and other auxiliary equipment of the ever more complex airplane, have to be revised when the airplane is considered a deformable rather than a rigid body. The seriousness of the problems of aerodynamic instability and flutter of wings, and control surfaces, has given great impetus to more extensive research in these fields.

When these engineering problems began to be realized in their true perspective a few years ago, effective engineering was hindered by the lack of actual data on the many related phenomena, nor were reliable test instruments available to the researcher who would investigate the problems. While in some instances laboratory apparatus was available, it would by no means stand the rigors of flight testing with any degree of reliability or economic justification. For instance, it became necessary to determine the actual landing accelerations encountered in large heavily-loaded airplanes when flown by the average pilot. These might in many cases be as much as five to ten times the acceleration of gravity, or even greater. Not only must the measuring equipment be able to measure these accelerations within close limits, but if mounted within the airplane, it must itself be subject to relatively high impact accelerations. It must therefore be sturdy, able to stand wide variation of atmospheric conditions, and, above all, it must be light and compact.

This instrumentation problem has been attacked from many angles and, as in many problems before this, the aircraft manufacturers and other research organizations have

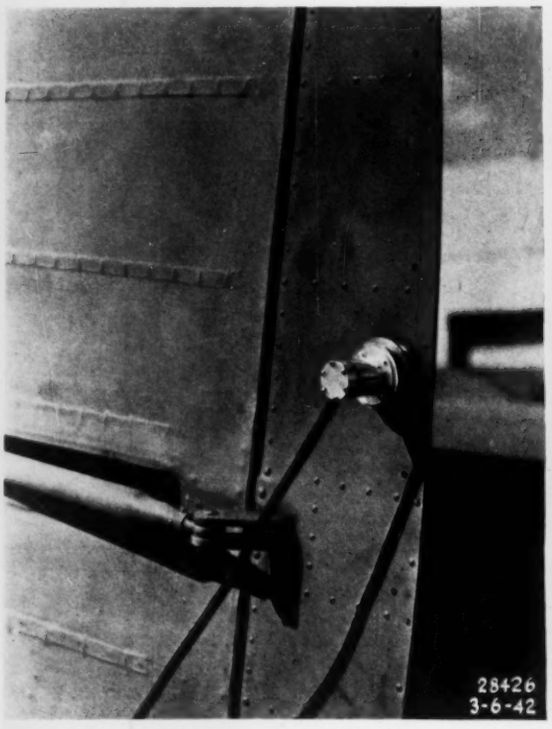
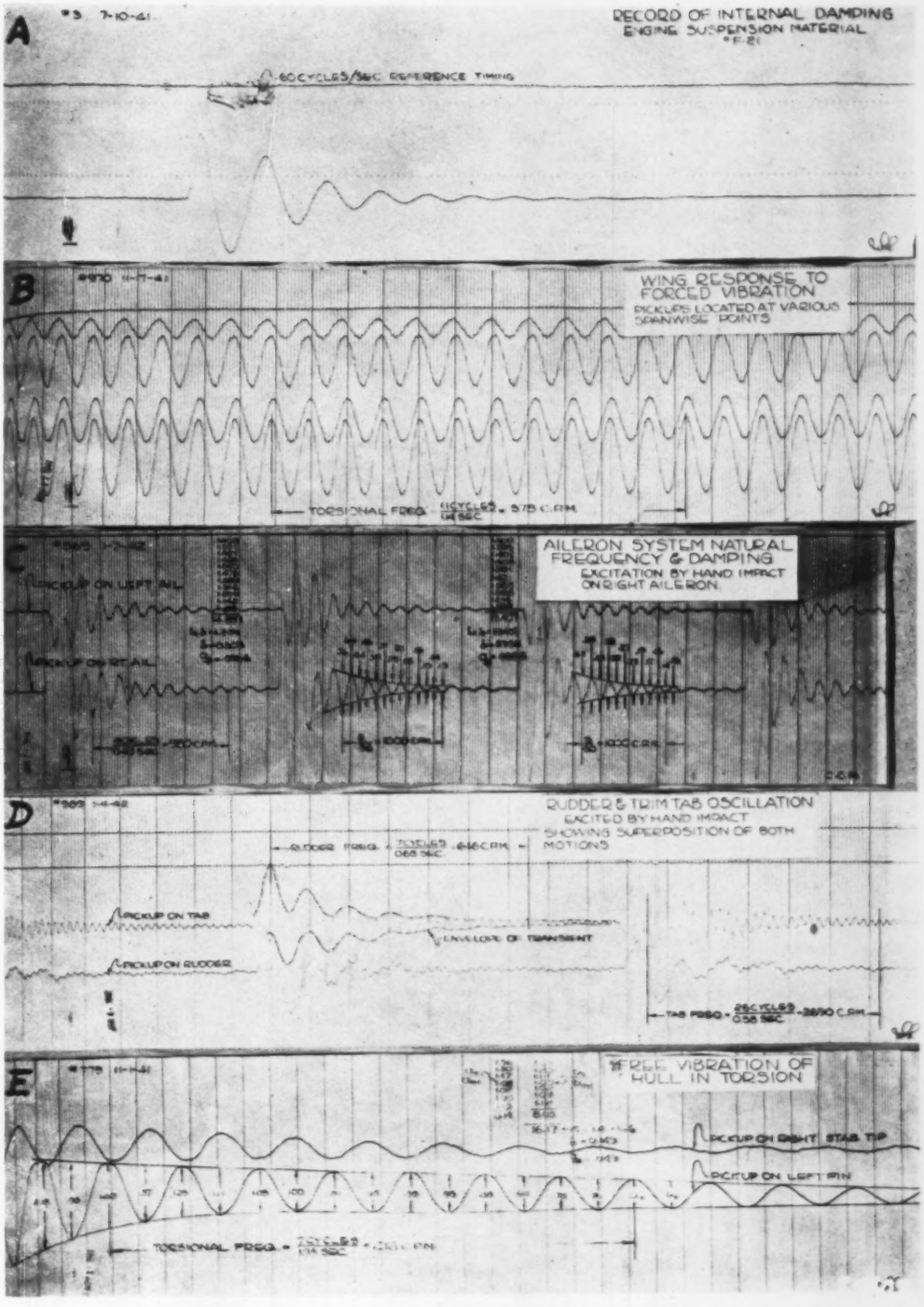


Fig. 2. Martin variable-reactance pickup mounted by quick-acting suction cup.

Fig. 3. View in Glenn L. Martin Instrument Laboratory where vibration equipment is built and tested.



4. Representative rec- obtained in miscellane- tests:

(A) Internal damping of en- mount shock-mounting rial.

(B) Amplitude of wing vi- ion.

(C) Aileron system in phase ration of both ailerons un- impact on one.

(D) Superposition of tab rudder vibrations upon pact.

(E) Free torsional vibration large flying boat hull.

had to solve the problem themselves and to develop their own systems of instrumentation in order to keep pace with airplane production demands.

Notable results have recently been released by the Glenn L. Martin Company whose experience in vibration research dates back to its design of large transoceanic flying boats several years ago. While the Martin engineers were primarily interested in vibrations in their initial researches, they have continually enlarged their experience and improved their technique so that they are now able, with a single set of equipment, to measure accurately vibrations, accelerations and strains, whether they be steady or oscillating, recurring or transient. Measurements have been many times, not only on all sorts of routine ground vibration tests, but also on aircraft in flight, takeoffs, landings, maneuvers and even during minor accidents.

The Martin equipment, since it is electrical, eliminates the multitude of dynamic and inertia errors to which purely mechanical systems in themselves are subject whenever an attempt is made to adapt them for so wide a range of service conditions as are experienced in aircraft use.

It became apparent at an early date that an accelerometer type pickup that could be readily mounted on any part of the airplane must be designed first, and the appropriate amplifying and recording equipment developed around it. A number of types of electrical accelerometers were investigated, several of which are shown in Fig. 1, which pictures the evolution of the Martin accelerometer pickup through major steps of its development. The design which is now being made available to the industry is approximately $1\frac{1}{8}$" in diameter by $1\frac{1}{4}$" high and weighs less than two ounces. It can be used to measure accelerations or vibrations from zero frequency up to 100 cycles per second, and is linear in its response up to twenty times the acceleration of gravity.

The amplifiers are designed to operate in conjunction with a standard commercial recording oscillograph which photographs the amplified pickup response on permanent roll paper film records from 6" to 12" wide. Several records showing typical results obtained during routine ground vibration tests are shown in Fig. 4.

But the Martin technique is not limited to the measurement of accelerations which furnish the designer with information pertaining to the loads applied to the airplane. Nor does it stop at the measurement of vibratory phenomena whether due to forced excitation, aerodynamic instability, turbulence of airflow and the like.

The same equipment has been designed to be used with the now-familiar wire filament strain gages* which can be easily cemented to the airplane structure as for instance, the wing spars, hull *(Continued on page 140)*

*See Professor deForest's article on page 112—Editor.

Absorbing the theoretical side of being an airplane mechanic, apprentices bend low over quiz questions in a classroom at LaGuardia Field.

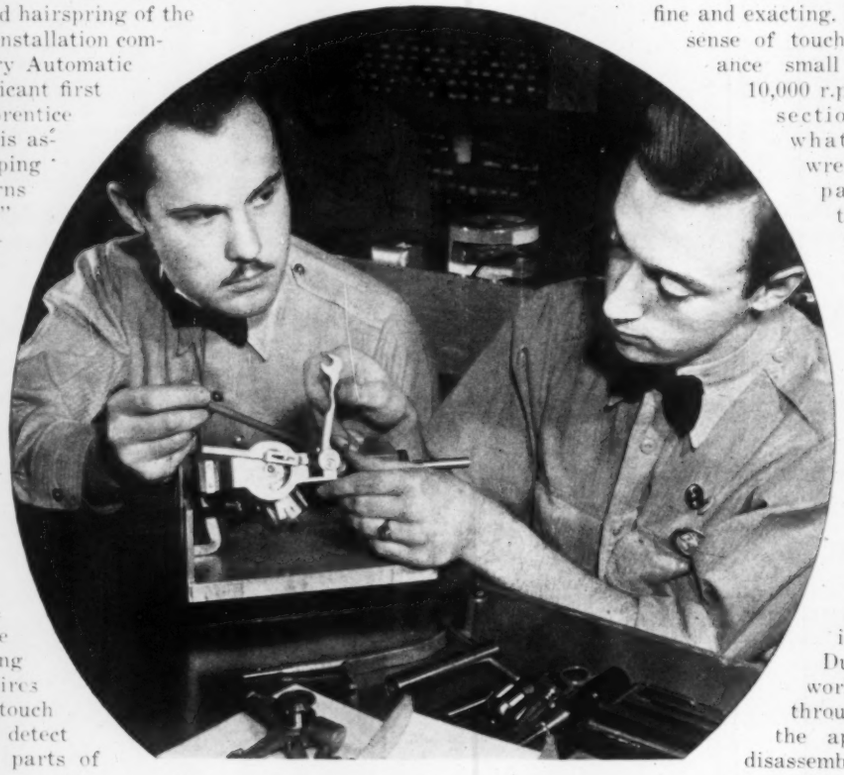
American Airlines' Four-year Mechanics' Course

By ROBERT H. BURCK

Senior Instrument Mechanic and Apprentice Instructor, American Airlines, Inc., La Guardia Field, N. Y.

PIONEER among airlines in the establishment of a recognized apprentice training system, American Airlines, Inc., today is turning out full-fledged mechanics with a well-rounded training obtained in classroom and shop during the four-year course.

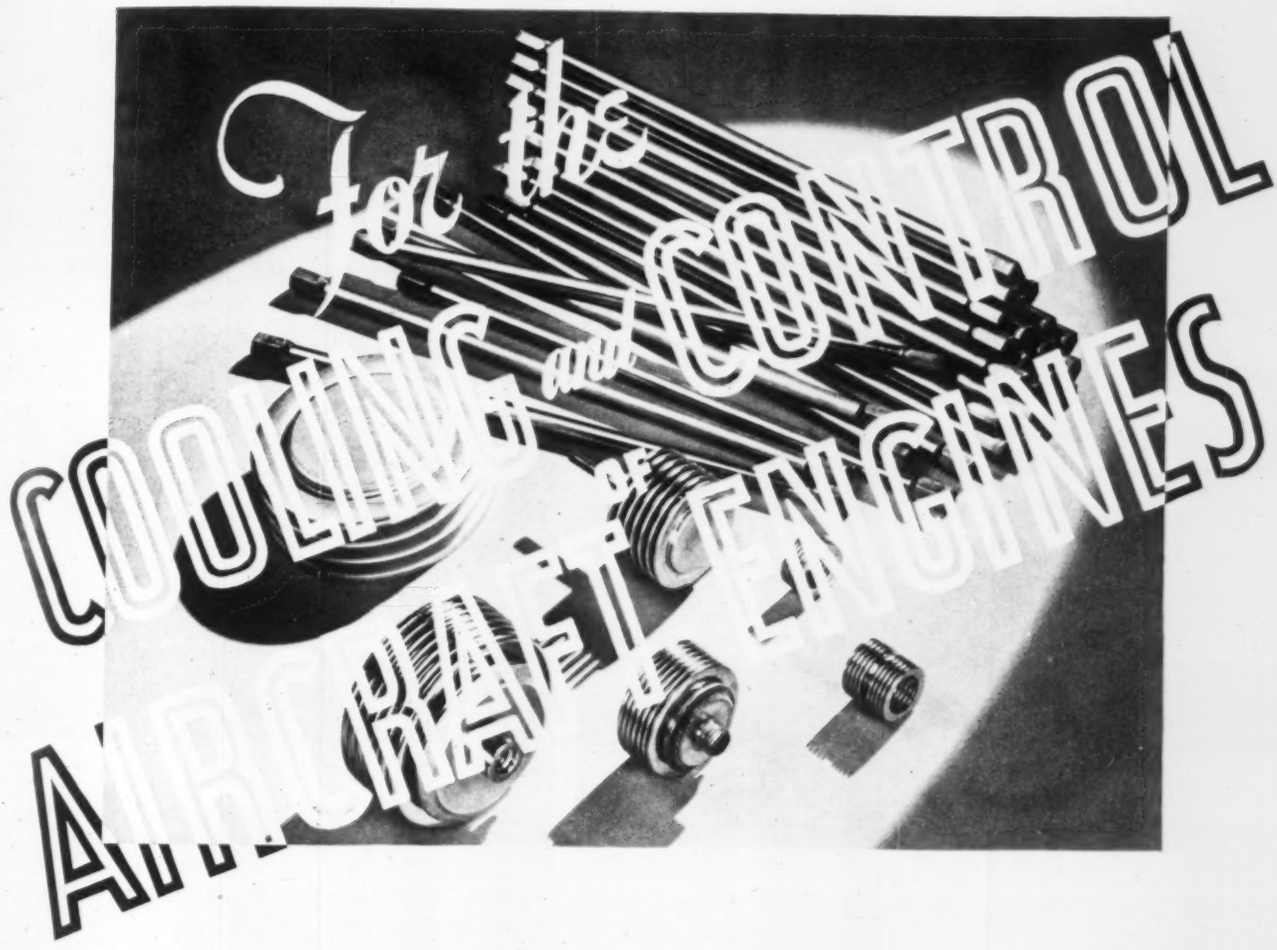
Specialized mechanics are schooled by several departments in the Maintenance Division, namely instrument overhaul, engine overhaul, and airplane overhaul. The instrument shop now has fourteen apprentices learning the intricacies of aircraft instruments from the smallest pivot and hairspring of the milliammeter to the installation complications of a Sperry Automatic Pilot. When an applicant first is accepted for apprentice training, he usually is assigned to the wrapping bench, where he learns the "do's and don'ts" of instrument packing. Simple as the task may appear, it is an important factor in assuring safe arrival of a newly-overhauled instrument which is sent to another station on the Flagship routes. Two months later, when he has also worked on record-keeping and stockroom, the apprentice moves to the lapping bench. Here he acquires the light instrument touch and the ability to detect dirt on the delicate parts of an instrument.



Walter Scharff, left, a senior mechanic in AA's Instrument Overhaul Shop, instructs Apprentice George Schlehr in the correct adjustments of a pointer bar on a Sperry artificial horizon.

Especially is he struck with the effect of dirt on the vacuum-actuated instruments, where he can observe the effects of "breathed" cigaret smoke. Always an interesting and exciting phase of the training is the introduction to aircraft work. Under the eye of a mechanic in charge of instrument installation for the airplane overhaul department, the apprentice learns the role played by instruments in the flying end of the industry. He studies their placement on the panel, the various system hookups such as the fuel analyzer, airspeed and static pressure systems, vacuum system, electrical system, and the automatic pilot system. He assists the mechanic in all airplane checks and frequently sees in operation the very instruments upon which he has worked in the shop. After two months in the airplane overhaul department, he is ready for training in the Sperry section, which includes the overhaul, calibration and check of the directional gyro, of the artificial horizon, and of the entire gyropilot with its many individual units. He finds that the automatic pilot really is a rather simple device but that tolerances of various fits are fine and exacting. He develops an acute sense of touch in learning to balance small rotors turning at 10,000 r.p.m. Here, as in other sections, he learns just what havoc dirt can wreak on the delicate parts. Not all his training is acquired in the shops: twice every week, for a total of four hours, he receives classroom and shop instruction in the evenings. The use of all instrument tools is demonstrated, and the apprentice learns the theories and principles of all instruments from competent instructors who are specialists in their fields. During this classroom work, which continues throughout the four years, the apprentice completely disassembles, overhauls, and reassembles every type of instrument used by American Airlines. The instrument shop foreman maintains an up-to-the-minute chart showing at a glance in what section each apprentice has studied and worked, how much theory he has received and when he is scheduled for transfer to another department for another phase in the training.

And when the four years have rolled by and he receives his graduation certificate, the mechanic is qualified *unreservedly* to execute the repair, overhaul, and installation of any instrument on a Flagship and to meet all the diverse day-by-day problems in his field.



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Government and Delta Give an Intensive Course for Aircraft Instrument Mechanics

By CARL F. NISBET, Jr.

Foreman, Instrument Overhaul Shop, Delta Air Corp., Atlanta, Georgia

EARLY in 1941 it became apparent that a scarcity of aircraft instrument mechanics existed in the United States. A group of watchmakers in Atlanta, Ga., realizing this shortage, appealed to the government for instruction.

Federal representatives contacted William Stevens and me, as veteran instrument mechanics for Delta Air Lines, about conducting a government class. We at first declined because we did not agree with their belief that a six-week course would be sufficient to transform the watchmakers into aircraft instrument mechanics.

The net result was that they gave us full authority in planning the course of study and the length of instruction period for a series of classes sponsored in Atlanta by the Federal Security Agency, U. S. Office of Education, and the War Department. The course runs six months, and classes are held four nights a week from 7:30 to 11:30 in an Atlanta high school. The schedule will soon be expanded to six nights each week.

In six months we feel confident that we can train a worker capable of handling the task assigned to him. Frequently the duties of an instrument mechanic for the government are restricted, or specialized, to the repairing of only a few instruments.

It takes at least two years of practical work to turn out a finished instrument worker for the commercial airlines, for he must be thoroughly familiar with all types of instruments and with their installation and removal.

While officials of the school do not guarantee jobs, the record shows almost 100 percent employment of graduates. One reason for the popularity of the classes is that the men have been able to nearly double their earning capacity in most cases.

For the most part, applicants are selected according to the date they filed their applications. We have about 250 on file now.

We limit each class to 24, but have two classes running at the same time, getting their lecture and theory work one night and their practical or laboratory work the next. For instance, right after they have a lecture on a standard altimeter, they go to the laboratory and work with that instrument first hand.

No particular education is required, but most of those in the class are high-school graduates. I first give each class the basic points they need about physics, mathematics, and meteorology. The course begins with two weeks of meteorology, taking up mercurial and aneroid barometers, their function, and what effect the weather has on the instruments themselves.

Aircraft instruments call for frequent overhaul because they are subjected to so much moving around, and to such wide variations of temperature and pressure. Naturally it is important for them to be accurate, as it is a matter of life or death if they are not.

Next, other instruments are taken up in turn. Drawings of each are put on the blackboard and the function, purpose, etc. are explained. The students are required to copy these drawings in their own notebooks. Among the instruments studied are the capillary temperature gage, oil and fuel pressure gages, pressure warning units, suction gage, manifold pressure gage, air speed indicator, Pitot static system, standard altimeter, sensitive altimeter, climb indicator, centrifugal tachometer, magnetic tachometer, electric tachometer, compasses, aircraft clocks, turn and bank indicator, Autosyns, Sperry directional gyroscope, and the Sperry horizon.

In the laboratory, conducted by Mr. Stevens, the various instruments are studied first-hand. Members of the class must learn how to remove and install them, and to disassemble, clean, inspect, reassemble, and calibrate. Each operation must be completed at least five separate times for

Student in foreground is calibrating an air-speed indicator.

Unposed shot of members of an advanced class intent upon their assigned task of cleaning and inspecting magnetic tachometers, oil pressure gages, climb indicators, sensitive altimeters, etc.

ABOVE—An apprentice watchmaker (left) inspects a tachometer; a veteran watchmaker (right) who has a job awaiting him on graduation, inspects a climb indicator.

CENTER—Carl Nisbet lectures on the climb indicator to a class; after which,

BELOW—William Stevens gives individual instruction on the same instrument.

ABOVE—These men are learning at first hand the construction of thermometers, turn-and-bank indicators and tachometers.

BELOW—Members of the newest class working on thermometers, air-speed indicators and standard altimeters.

every instrument. They learn also how to run different lines to the instruments, methods of soldering connections, flaring tubing, shock mounting, and some lathe work.

Five tests are given during the course, and the men are recommended for jobs on the basis of their industry, efficiency, carefulness, and skill.

Out of each group there is a certain number—about 25 or 30 percent—who can't make the grade. We can usually tell who they are in two to four weeks.

A man who misses eight classes is dropped; but we are fortunate in having most people deeply interested in their work—they have to be, to come four hours, four nights every week, after a full day at their regular jobs.

The course costs them nothing, except for a textbook, as the government furnishes all equipment.

There have been no women in the class. No doubt this is partly because the government is not hiring women for this work right now, but I see no reason why they couldn't do it.

Our class is one of only two that I know of in the United States which are conducted by the government and open to the public.

Stevens and I agree we are learning as much from the classes as we are teaching the students.

They ask a lot of questions and we have to be sure of the right answers before we give them out. As Stevens says, "I have to show them a certain operation so many times that, when that job comes up during my regular work at Delta, I can sit down and do it much faster than I used to."

Members of the class are of all ages and in various types of occupations. Previous education and experience seem to have little to do with the ability of the individual to master this skill.

Take, for instance, the case of a former department store beautician. At the end of the six-month course, he was placed at the Wellston Air Depot, in Macon, Ga., at a salary of $2200 per year.

A former watchmaker and another former beautician were placed here starting at $1860 per year, after finishing five months of the course.

Two former meter overhaul men for the Georgia Power Company took similar jobs after little more than four months' training.

(Continued on page 138)

Functions of the TWA Instrument Department

By WILLIAM P. DANKE

Foreman, Instrument Dept., Transcontinental & Western Air Inc., Kansas City, Mo.

I THINK I can say without fear of contradiction that instruments are truly the life-blood of modern air transportation. If aircraft instruments had not been perfected, the great network of airlines criss-crossing our nation could never have been developed. Aviation still would be in the era of barnstormers and thrill seekers. Safe, comfortable flying on regular schedules would be out of the question. The maintenance, repair and overhaul of aircraft instruments, plus a program directed toward improvement or development of new ones, are important functions of an airline. The instrument department of TWA is charged with all these responsibilities. The instruments that come under our department include all navigation, engine and standard flight instruments; de-icer accessories; vacuum and hydraulic pumps and cabin supercharger equipment. TWA and Pan American are the only two airlines working with supercharging equipment as the high-altitude Boeing Stratoliners are the only planes employing pressurized cabins. Our department, quartered at the TWA main base in Kansas City, Mo., is divided into four divisions: Gyroscopic Instrument Shop; Navigation and Standard Flight Instrument Shop; Accessory Overhaul Shop; and Maintenance, Repair and Service Division.

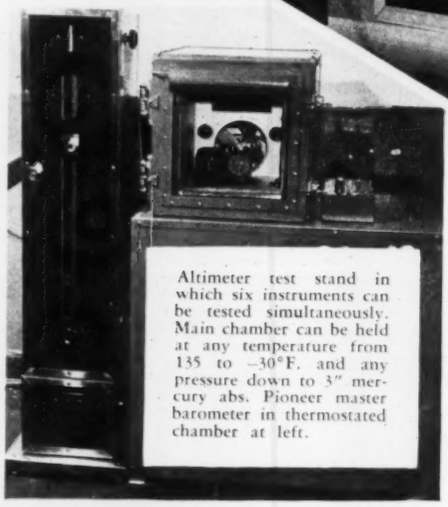
Thirty-nine men are employed in the department, of which approximately 50% have government airplane or engine licenses, or both. There are one Crew Chief and two Master Mechanics.

In the standard flight instrument shop we maintain the supervision, coördination and work control of all four shops in addition to the time control of all instruments over the entire coast-to-coast system of TWA. Time control, which keeps track of every instrument and can tell us the total service time on any instrument at the end of every day, would require a separate article to adequately describe its operations.

We also have trained instrument men and ample spare parts and instruments at New York, Pittsburgh, Chicago, Los Angeles and San Francisco, but all major overhaul is done in Kansas City.

Three of the most important activities in Kansas City are (1) personnel training, (2) design and manufacture of shop and service equipment and (3) experimental development of new instrument design. By reason of the National emergency, personnel training is a particularly vital activity. During the past year a considerable number of instrument mechanics have entered the armed forces, necessitating a schooling program in which we can instruct men with basic mechanical experience to become expert instrument technicians in the shortest possible time. Approximately 1500 to 2000 units pass through the department each month. It is necessary to train instrument mechanics who are capable of handling overhaul and calibrating procedures on all types of instruments. Most of our mechanics are graduates of our apprentice instrument system which begins with the maintenance division and progressively moves through all phases of each of the other three shops.

The author running a test on the Turn and Bank Calibration Stand developed by TWA's Instrument Department, whereby a rated turn of 3 degrees per second (TWA standard) can be maintained to greater accuracy than formerly possible.



Altimeter test stand in which six instruments can be tested simultaneously. Main chamber can be held at any temperature from 135 to −30°F. and any pressure down to 3" mercury abs. Pioneer master barometer in thermostated chamber at left.

Each of the instruments is removed from our aircraft at the end of 600 flying hours for periodic repair. They are disassembled, cleaned and inspected and recalibrated on equipment which has been designed to simulate actual flying conditions as well as check accuracy against calibrated standards which are held to much higher standards of specifications than the original factory calibration. After from 1500 to 3000 flying hours (depending on the type of instrument) these same instruments are completely overhauled and rebuilt.

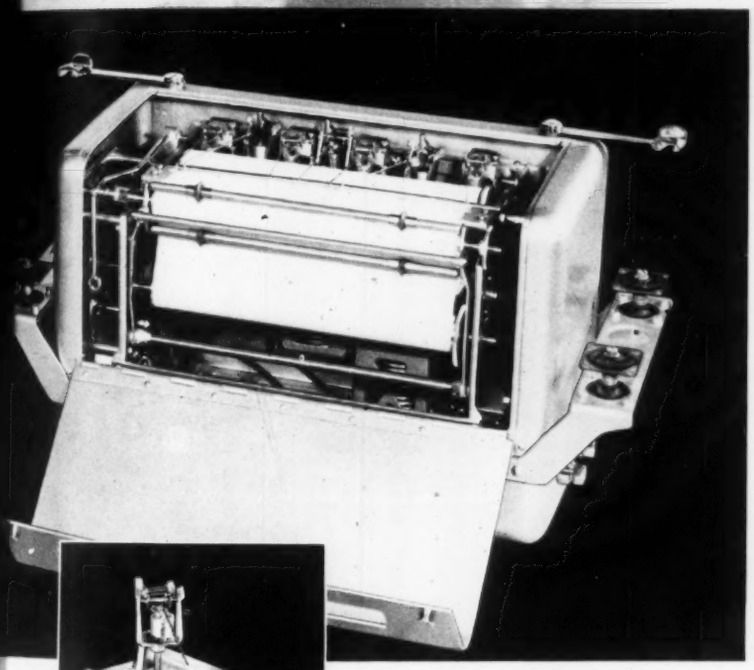
We have reason to be especially proud of the Design and Development Section of our department. We have designed and built several new developments that contribute materially to our test facilities as well as do certain jobs faster and more efficiently. These include (see illustrations)

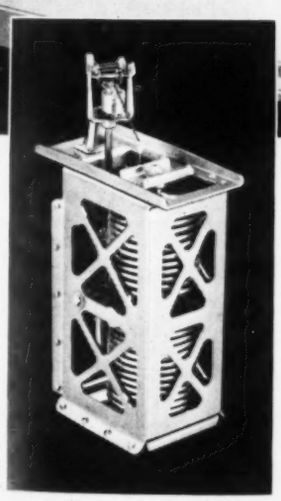
(1) A Turn and Bank Calibration Stand, by which a rated turn of 3 degrees per second (which is TWA standard rate of turn in all instrument flying procedures) can be maintained to a far greater accuracy than formerly was

(Continued on page 137)

Al Jordan, Crew Chief of TWA's Instrument Department, working on the stroboscopic tachometer calibrating stand comprising a synchronous motor, variable-reduction gear box, manifold drive for six tachometers, and stroboscope.

"It KEEPS the LOG" at 500 M.P.H.





Above: The Friez Flight Analyzer. It is possible with recording instruments of this type to cover such functions as altitude, vertical acceleration, air speed, carburetor manifold pressure, engine RPM, cable control motion, passing of radio beacons, the operation of gyro pilot, radio transmitter operation, de-icer operation, etc., etc.

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At left: One of the Sylphon Bellows actuated units of the Friez Flight Analyzer.

Designed to provide a written record, automatically, of practically everything that happens on board a plane in flight—including the psychological reaction of the pilot—the amazing Friez Flight Analyzer is standard equipment on every U. S. airliner and widely used by airplane manufacturers, the Army Air Corps, the Navy and the Civil Aeronautics Authority.

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Concentricity Checking Machine for Airplane Rocker Arm Bearings

By J. R. DRUMMOND
Chief Engineer, The Timken Roller Bearing Co., Canton, Ohio

Illustrations on facing page

OUR entrance into the war has emphasized the vital importance of the operation of aircraft motors with the minimum of attention. One of the critical points of radial engines is the rocker arm bearing. Timken rocker arm bearings take a combination of radial load from the valve action and thrust load from the angularity of the push rod. The bearing consists of a double inner race and two single outer races spread apart by a horseshoe spacer to give proper internal operating clearance. This article describes (chiefly by means of self-explanatory illustrations) a machine for checking the cup concentricity on rocker arm bearings, which is believed to be ideally suited to its application.

The cups in the rocker arm assemblies have a small rib at the extreme end of their O.D., and instead of just checking the cup O.D. runout, as is necessary in ordinary bearing cups, it also is necessary to check the runout of this rib on the cup. In this respect, the machine is unique in that it can check the runout of the cup O.D. at the same time that it is checking the runout of the cup rib.

The principal features of this machine are to have the cone held stationary and have it centered on a stud; turn the cup by means of a floating pressure plate; and take the readings on two dial gages (graduated in ten-thousandths) by means of two levers which retract when the spindle, which carries the floating pressure plate, moves up.

Note that the hinges of the gage levers are formed by spring blades. The up-and-down motion of the spindle, which is over-balanced by a counterweight, is obtained from a foot pedal. The downward pressure of the floating pressure plate is produced by an adjustable spring. When the spindle goes up, the pressure plate holder centers itself in the tapered bore, but it is lifted out of this bore in the gaging position.

Only one simple part changeover is required to set this machine up for checking a specific bearing assembly. The pressure plate, which revolves the assembly, and the adapter, on which the assembly is mounted, must both be installed to suit the assembly to be checked.

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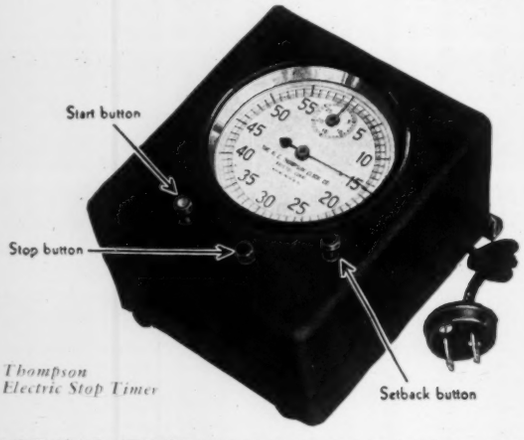

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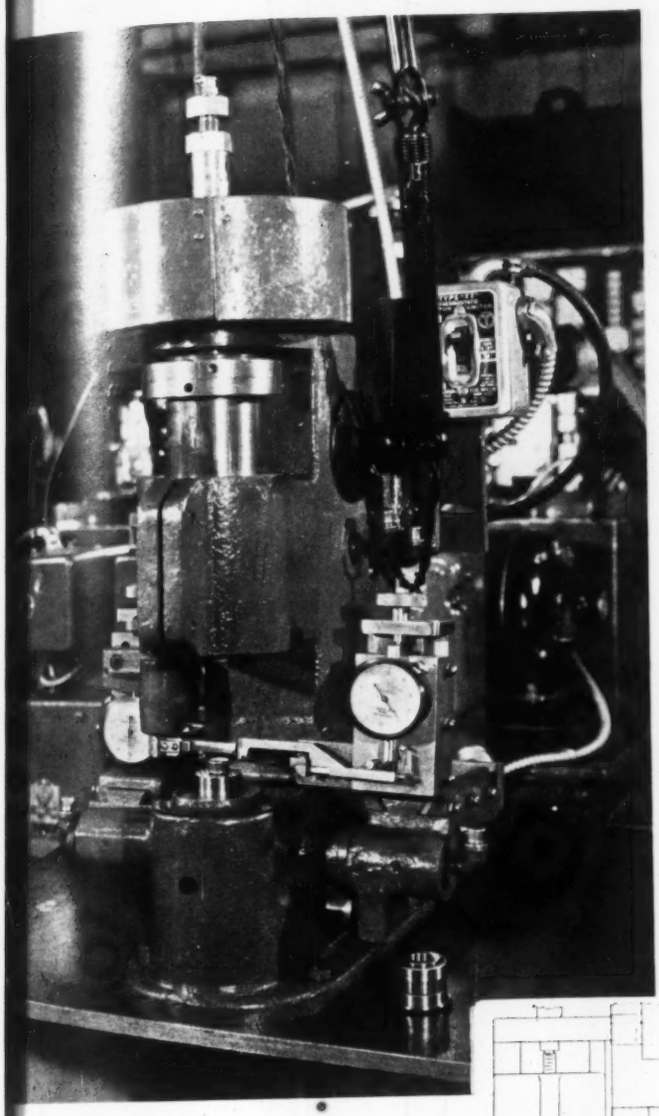
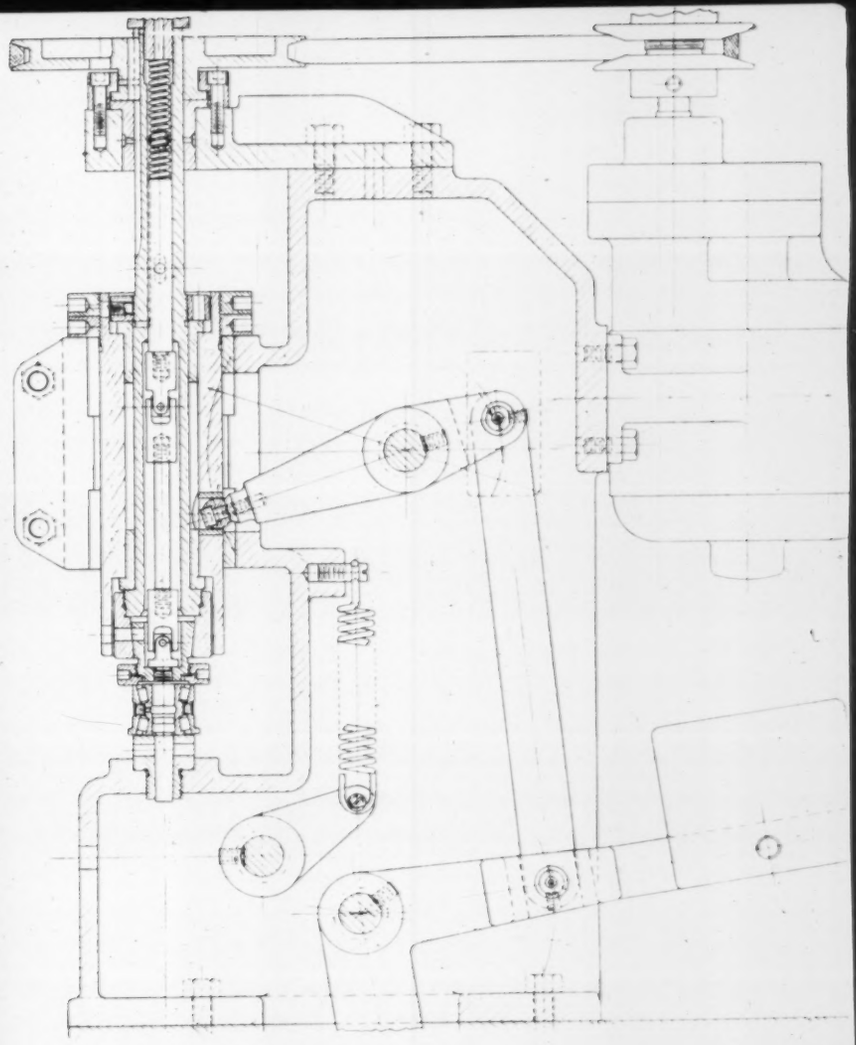
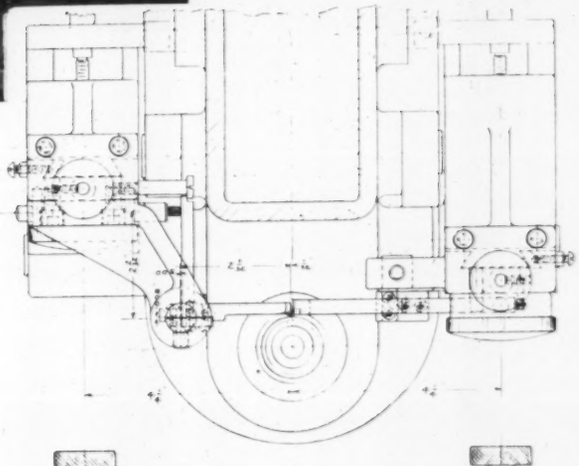
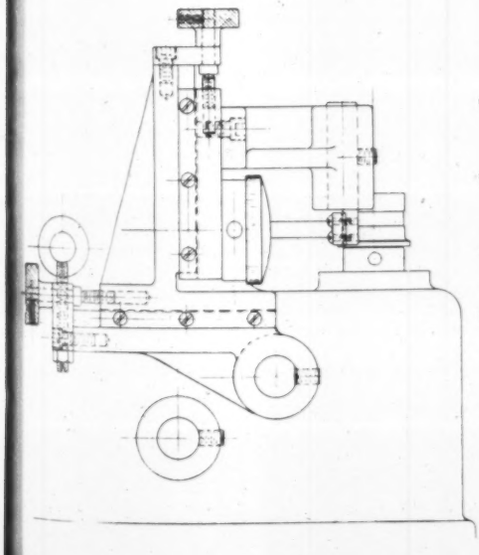
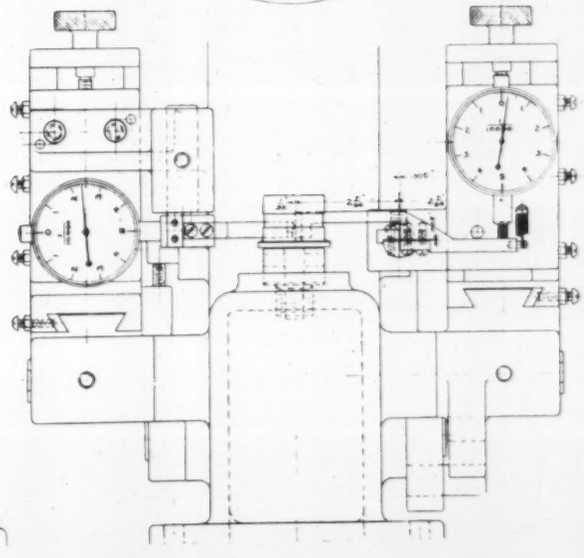
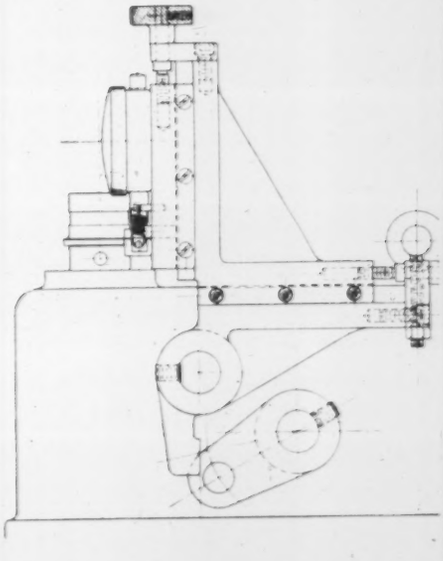












Twelve-point Recorder Facilitates Analyses of Heat Treatment Processes

By SELIG H. ISAACS

Instrument Engineer, Wright Aeronautical Corp., Cincinnati, Ohio

NOW that accurate and sensitive temperature control mechanisms have become a standard part of almost every heat-treating unit, the importance of properly distributing the temperature throughout the heating space is becoming more clearly recognized. It is a normal psychological attitude on the part of operating departments to place such problems squarely in the hands of their instrument maintenance departments for, regardless of assurances that the instruments themselves are in satisfactory calibration, the results of incorrect heat-treatment temperatures are obvious. The instrument service group must therefore at least go so far in the study of the problem as to substantiate their claims of instrument accuracy and to picture for the operating department the actual conditions within the oven.

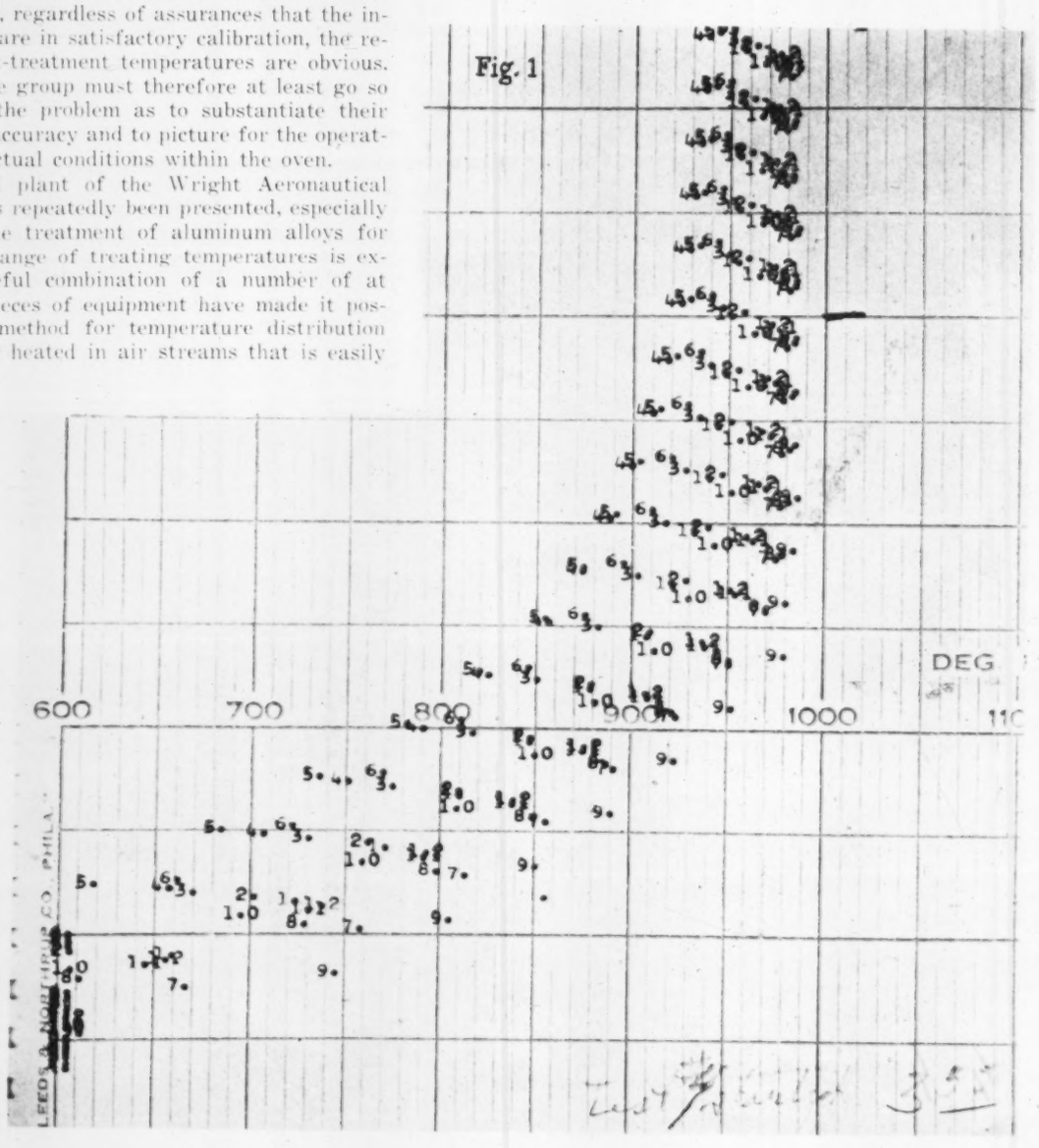
At a newly-erected plant of the Wright Aeronautical Corp. this problem has repeatedly been presented, especially in connection with the treatment of aluminum alloys for which the allowable range of treating temperatures is extremely narrow. Careful combination of a number of at least semi-standard pieces of equipment have made it possible to work out a method for temperature distribution study on metals being heated in air streams that is easily set up and relatively portable. This method in most cases interferes almost not at all with the functioning of the process while the test is being carried out.

The method is based primarily on the use of 20-gage duplex iron and constantan thermocouple wires in which each wire is covered with braided asbestos, and there is an asbestos braid overall. The covering must be free of any organic binder. This wire has the advantages of being flexible, not too bulky, and resistant to temperatures somewhat in excess of 1000° F. without additional protection. It will not stand abrasion and therefore is useful only for a limited number of tests.

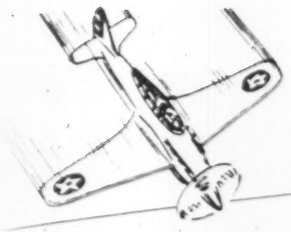
Thermocouples are made of this wire; and the junctions placed in the load in such a way that the actual metal temperature is observed. The number of couples installed, the method of bringing the wires outside the furnace and the length of the couples must be determined for each individual furnace. It is then possible to connect these couples to a portable potentiometer indicator through a multipoint switch, and make a series of temperature observations at definite intervals as the work passes through the furnace.

It has been found more expedient and better from the standpoint of analyzing the results, however, to use a potentiometer recorder. We are employing a 12-point strip-chart recorder with 20 seconds per point printing speed, 4" per hour chart speed, and ranges of either 0 to 1000° F. or 600 to 1600° F. The range is selected by a toggle switch, and the process itself determines the range that is to be used. Fig. 1 shows a typical portion of a chart taken from a metal-heating process. The test report usually consists of a diagram of couple locations, a brief description of any special test conditions that might have been imposed, and photostats of the test instrument record. Such a record is usually much easier to analyze and convert into meaningful data in terms of the process itself than any list of manually observed and logged temperatures that, on a multicouple test, will usually cover a number of pages.

Fig. 1



The results of these analyses have already contributed to both major and minor design changes in certain ovens, to a more complete picture of what might be required of future designs, and to more intelligent operation of present equipment.



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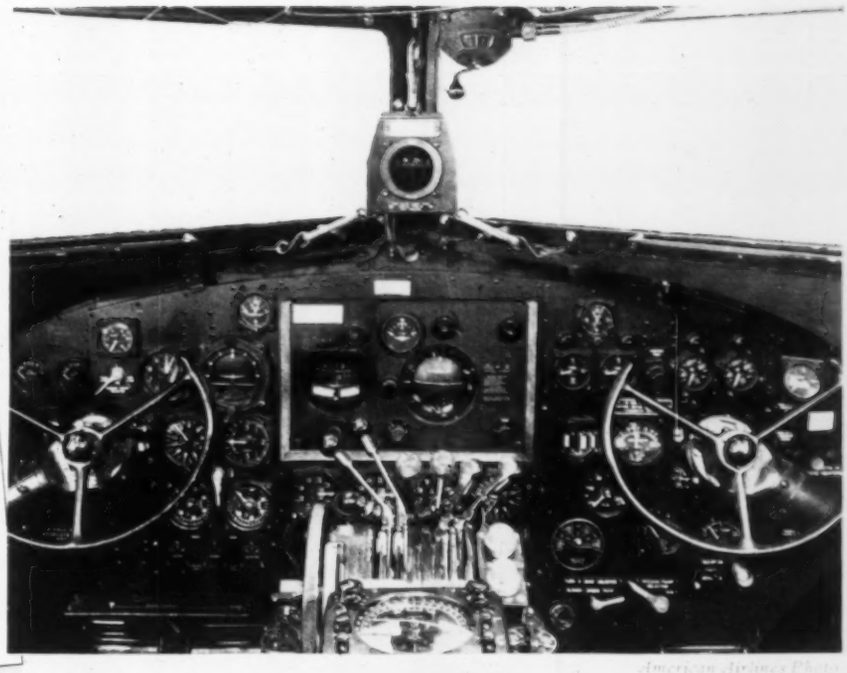

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Guide Vanes for the Cup Anemometer

By ALEXANDER KLEMIN and W. C. WALLING
Guggenheim Research Professor Graduate Assistant
New York University, New York City

THE CUP ANEMOMETER, whether of the rotating or the stationary pressure type, cannot indicate below a certain speed. If there were no frictional torque to overcome, the instrument would be theoretically capable of indicating down to zero velocity. If the frictional torque is assumed to be independent of the wind speed (as it is in all probability) the speed of indication may be represented for the rotating-cup anemometer by an equation of the general form:

$$Q_f = K_1 (V - \omega R)^2 - K_2 (V + \omega R)^2$$

where

Q_f = frictional torque.

K_1 = a constant appropriate to the aerodynamic moment produced by the concave cup surface retreating from the wind,

K_2 = a constant appropriate to the aerodynamic moment produced by the convex cup surface advancing into the wind,

V = velocity of the air-stream,

ωR = a quantity representative of the rotational velocity of the cups,

ω = angular velocity,

R = radius.

When the anemometer ceases to indicate, we have

$$Q_f = K_1 V^2 - K_2 V^2 = (K_1 - K_2) V^2$$

so that $V^2 = Q_f / (K_1 - K_2)$ and $V = \sqrt{[Q_f / (K_1 - K_2)]}$

If the velocity of the air-stream were by some method increased to nV at its point of contact with the anemometer, the equation would become

$$(nV)^2 = Q_f / (K_1 - K_2)$$

$$V = (1/n) \sqrt{[Q_f / (K_1 - K_2)]}$$

so that the minimum velocity of indication would vary inversely as n.

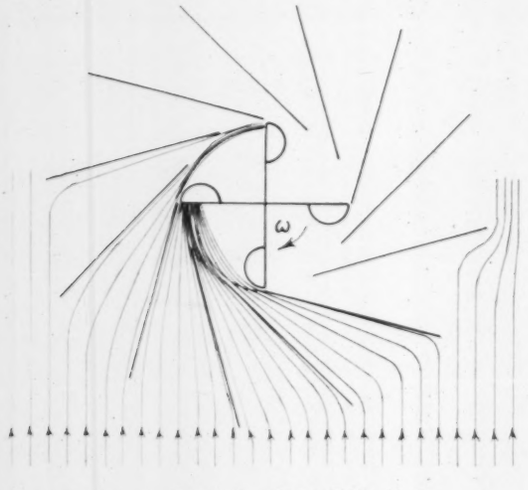


Fig. 1. Principles of the Guide Vanes

Of course, in view of the real complexity of the theory of the Robinson cup anemometer, and of its variability of performance, these equations should not be considered exact but merely indicative of the basic principles.

If the anemometer is of the "bridled cup" type, where the cups move slightly against the action of a spring, the minimum velocity of indication would likewise be reduced, since with this type also aerodynamic forces due to wind velocity are balanced by frictional forces.

It occurred some time ago to the first author of this article that if suitable stationary guide vanes were provided for the cup anemometer, the velocity acting on the cups might be increased and the minimum velocity of indication might be reduced without recourse to highly delicate and expensive design. The standard anemometer of commerce could then be made to give indications of lower velocity—an advantage in certain uses of the instrument.

The character of the guide vanes is illustrated diagrammatically in Fig. 1, and from this diagram it may be surmised that the effective velocity acting on the anemometer cups would be increased for two reasons:

(1) The area of the stream affected is increased, and since all the air affected by the external diameter of the guide vanes is obliged to pass through the area represented by their internal diameter, a Venturi effect is produced.

(2) The inclination of the vanes to the tangent of the inner circumference tends to increase still further the velocity of air impinging on the concave side of the cups and to shelter the cups presenting a convex surface to the air-stream.

To verify or disprove the above hypothesis, a number of simple experiments were carried out in the four-foot wind tunnel of New York University with application of guide vanes to a conventional rotating-cup anemometer.

APPARATUS AND EXPERIMENTAL METHODS

The tests were conducted on a M. C. Stewart four-cup anemometer, with cups of 2½" diameter and a circle of 11" diameter scribed by the rotating cups. The Stewart anemometer is provided with dry cells, light bulb, reduction gearing, contact maker, etc., so that the number of flashes per minute is an indication of the wind velocity. The character of the experimentation was simple. The anemometer was placed on a suitable stand in the four-foot wind tunnel. The velocity indicated by the anemometer without vanes was recorded for a given tunnel velocity. The test was then repeated at the same tunnel speed with guide vanes in position, and the velocity was again recorded. The percentage increase in indicated velocity was taken to be a measure of effectiveness of the guide vanes. The actual experimental apparatus is indicated diagrammatically in Figs. 2 and 3, which show three types of guide vanes, two trapezoidal and one rectangular.

Actual details of design, methods of securing vanes, of changing their angular position, etc., are of little importance. It should be stated that the apparatus employed throughout was home-made and rather crude, and introduced much unnecessary aerodynamic disturbance. It should also be noted that in addition to guide vanes, cone-shaped hoods were investigated which constituted a species of Venturi of revolution.

The tests were undertaken at wind tunnel speeds of 12 and 18 miles per hour.

PURPOSES OF TESTS UNDERTAKEN

It is not essential for the purpose of this paper to classify or describe the experiments in great detail. General classification and concise presentation of the main findings is sufficient.

The purposes of the tests are best set forth by listing the questions to which replies are sought:

(1) What is the effect of the number of guide vanes employed?
(2) What is the effect of the angular setting of the vanes?
(3) What is the difference in effectiveness of trapezoidal and rectangular vanes?
(4) Is the Venturi hood of any value?
(5) Is the combination of Venturi hood and guide vanes desirable?
(6) Does the instrument retain its linearity after application of the guide vanes?
(7) How important is the orientation of the air-stream to the guide vanes?
(8) Will any advantage be obtained by altering the angle of the anemometer cups in relation to the supporting arms?
(9) With utilization of the best means disclosed so far, what increase in indicated velocity may be expected?
(10) What increase in indicated velocity may be expected with further research?

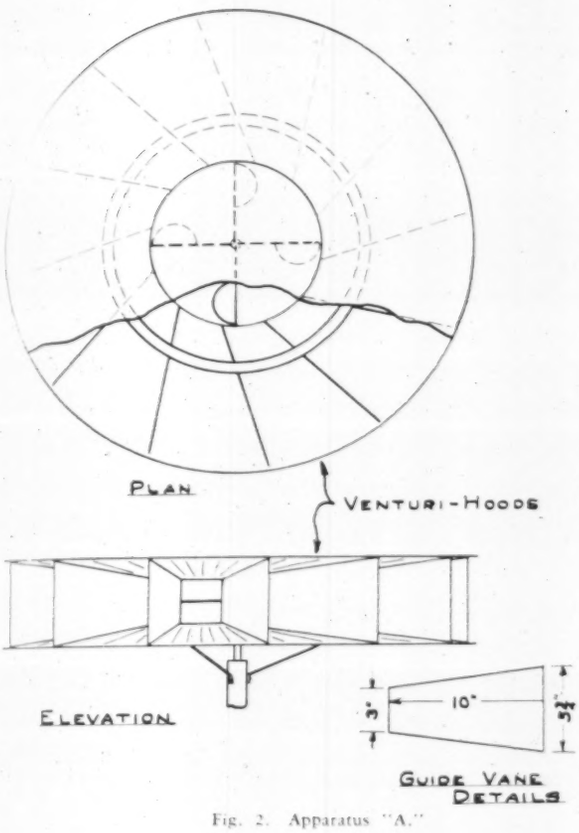


Fig. 2. Apparatus "A."

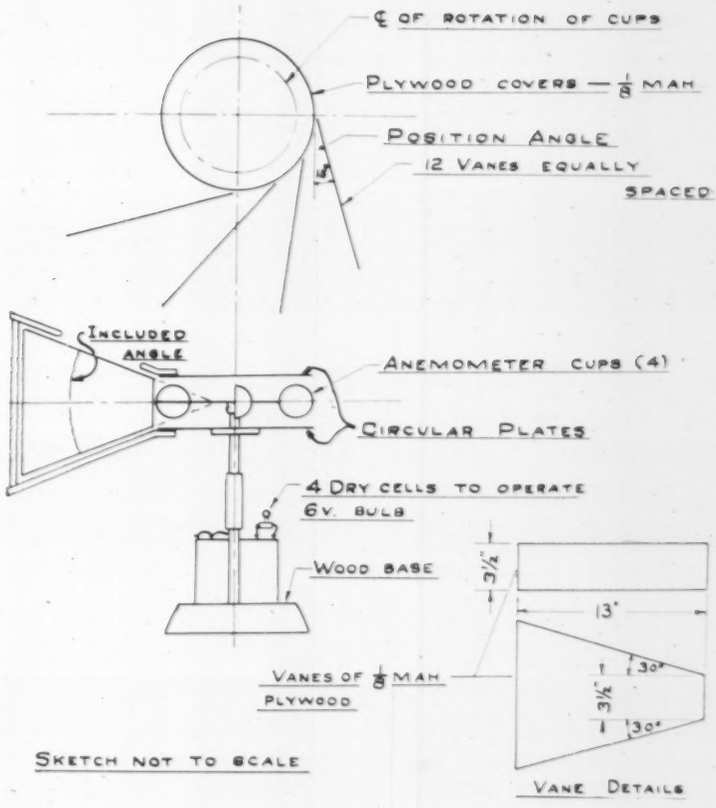


Fig. 3. Diagram of Apparatus "B."

DISCUSSION OF RESULTS

1. *Effect of the number of guide vanes employed:* The effects of using 16, 8, or 4 guides vanes were investigated in an early group of tests. The vanes (Fig. 3) were set in a 60° Venturi hood at a position angle of vane to cup tangent of approximately 30°. Using 16 guide vanes, the wind velocity was increased 47%; with 8 vanes the increase rose to 50%. However, when the apparatus was rotated 22½° (8 vanes are 45° apart), the increase fell to 40%. Using four vanes (90° apart), the velocity showed a 35% increase in one position and a 15% loss when the apparatus was rotated 45°. These results show that at least 12 vanes are necessary to get substantial increase in velocity coupled with independence of wind direction.

2. *Effect of guide vane angular setting:* Tests were run with the guide vanes set respectively at position angles (Fig. 3) of 90°, 60°, 45°, 30°, 20°, 15°, and 10°, measured from the tangent to the outer circle scribed by the rotating cups. At 12 mph, with the vanes set at 90° to this tangent (that is, set radially from the center of the rotating cups), the anemometer was slowed down 32%. This might be explained by the hypothesis that the air is directed away from the cups and concentrated at the center of the anemometer. However, as the angle was decreased, the results rose until at 15° a high of 103% increase was attained. At angles less than 15° the results fell off rapidly. The effect of angular position of the vane is indicated by the curve of Fig. 4.

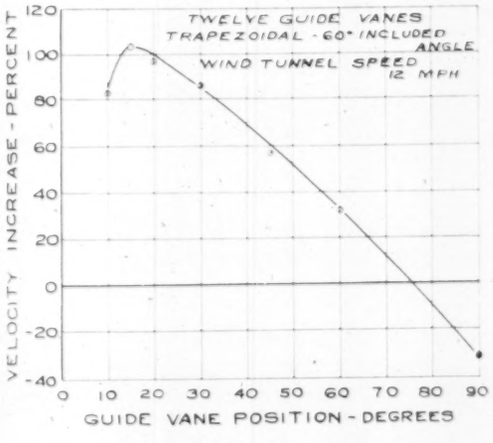


Fig. 4. Effect of Guide Vane Angular Setting

3. *Effect of guide vane shape:* Tests on vane angle setting were run with trapezoidal vanes with a 60° inclined angle, as shown in Fig. 3. When these vanes were cut down to a rectangular shape 3½" wide (the width of the inner edge of the trapezoid) and tested at the optimum angle setting of 15°, the increase of speed fell from 103% to 65%. Apparently, edge effects occur above and below the apparatus, and the trapezoidal vane serves the same purpose as might be served by a very wide rectangular vane in eliminating edge effects.

4. *Effect of Venturi-hood:* Tests were run with three Venturi type hoods each having a different included angle. It was found that a 0° hood had no effect, a 30° hood speeded up the air about 15%, and the 60° hood produced about 20% increase.

5. *Effect of combination of Venturi-hood and 12 guide vanes:* It was hoped that the 103% increase obtained with the 12 guide vanes at 15° to the tangent, combined with the 20% increase of the 60° venturi-hood, would give an even better result. Instead, the velocity increase with the combination of hood and vanes fell off to 56%. Apparently, the design of the Venturi-hoods is too abrupt in change of passage and creates considerable turbulence.

6. *Linearity with guide vanes in position:* The relationship between air speed and the rotational velocity of the ordinary cup anemometer is approximately linear. To check whether this relationship was altered or not by the application of the guide vanes, the indicated anemometer velocities

were recorded for a number of wind tunnel velocities. These results, as plotted in Fig. 5, show that an approximately linear relationship is retained. The number of rectangular vanes employed in this test was twelve, set first at 15° and then at 45°.

7. *Effect of orientation of the air stream:* A run was made with twelve guide vanes 30° apart at various velocities. A second run was made by rotating the apparatus 15°, thus giving two critical positions. The results of this test are shown by curve of Fig. 6. At a wind tunnel velocity of 20 mph, the anemometer velocity differed 3 mph for the two positions. However, at three miles tunnel speed, the difference was only 0.3 mph, approximately. Considering these results, it would seem advisable to use 16 or 18 guide vanes to reduce the effect of orientation of the air stream.

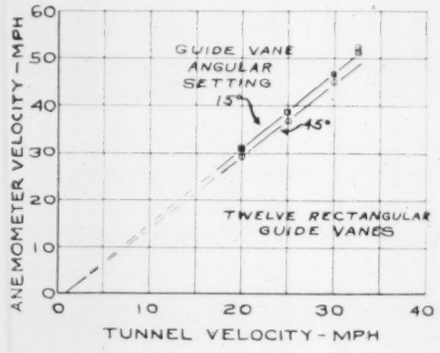


Fig. 5. Linear Relationship Tests

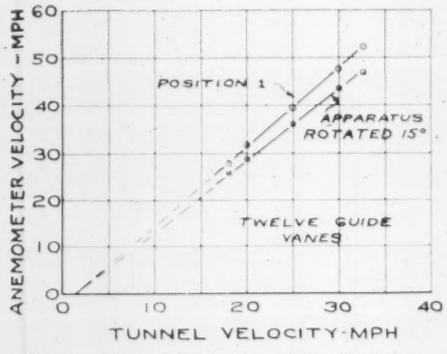


Fig. 6. Effect of Orientation of the Air Stream

8. *Bending cups back:* Finally, it was found that by bending back the cups 15°, so that, as indicated in Fig. 1, the air strikes them more normally, the best results of 103% increase were raised to 109%.

9. *Aerodynamic Cleanliness:* It should be emphasized that the apparatus used in this research was "dirty" aerodynamically. For example, so that apparatus might be sturdy in the tunnel, the wood frame supporting the guide vanes was made bulky. It is not overly optimistic to predict an additional increase of velocity with more streamlined apparatus. Some of the experiments give support to this contention. The initial experiments made use of a much "cleaner" framework, but it was not suited for adjustments of the guide vane position angle. With a later framework in which position angle could be varied, but which gave a "dirtier" apparatus, the same angular setting reduced speed to about two-thirds of the speed attained with the "cleaner" apparatus.

SUGGESTIONS FOR FURTHER RESEARCH

If it is found desirable to continue research, experiments might well be along the following lines:

1. A refined apparatus based on the best conditions found to date should be tested first. The vane and framework should be "clean" metal construction, sturdy enough to withstand reasonably strong winds. Sixteen to eighteen guide vanes should be used, set at a position of 15° to the tangent. The vanes should be about 12" long, trapezoidal in shape, with the inner edge somewhat larger than the diameter of the anemometer cups.

2. The effect of a pair of circular plates, one above and one below the cups as shown in Fig. 3, might be tested. Perhaps these would keep the air above and below the cups from "spilling" and creating turbulence.

3. A logical suggestion is to curve the guide vanes as shown in Fig. 7, in order that the course of the air will be changed gradually. The outer edge of the vanes would be radial, and they would gradually curve so that the inner edge would be 15° to the tangent.

4. It is possible that the cone-shaped Venturi-hoods with an included angle of 60° cause considerable turbulence at the vertex, thereby nullifying the advantage gained by the Venturi-hood effect. However, if these hoods were so designed that the air was smoothly straightened out before entering the cups (such that the passage formed by two guide vanes and the hoods would approach a Pgandtl wind tunnel entry), an advantage through their use might be realized.

5. Another possible line of research would be to cut down the length of the anemometer cup arms while retaining the large external diameter of the vanes, in this way increasing the air-capturing effect.

6. Experiments in application of the vanes to other makes of anemometers, rotating and bridled cup type, should be undertaken.

7. In the 4-ft. wind tunnel in which the experiments were made, the speed of the air stream could not be reduced below 10 mph. Since the main object of the vanes is to reduce the minimum speed of indication, it would be highly desirable to carry the range of experimentation down to the very lowest velocities either in a tunnel with wider speed range, or in free air, or with a simple type of whirling arm.

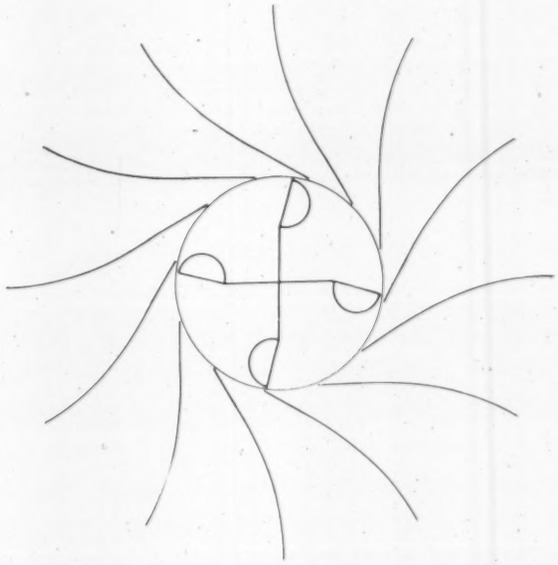


Fig. 7. Proposed Curved Guide Vanes for Cup Anemometers. Outer edge of vane is radial, inner edge 15° from tangent. Note: Cups are bent back 15°.

GENERAL CONCLUSIONS

A definitely increased velocity, nV, for an air stream of velocity V, has been obtained by the use of guide vanes. Since the stopping or starting speed of the anemometer was shown to be approximately universally proportional to n and since an n of 2.09 was obtained in these experiments, the stopping speed should be reduced about 50%. However, it is reasonable to expect that even better results will develop through the use of a refined apparatus and by further research.

In closing, it might be well to suggest a few practical applications for the standard anemometer of commerce if it can be made to function at low stopping speeds:

(a) Indication of low wind velocities in connection with chemical warfare.

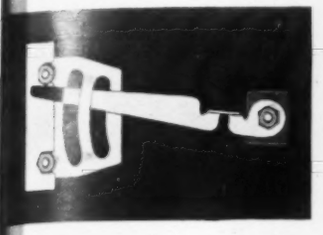
(b) Measurement of wind velocities passing over an evaporation pan set in deep woods.

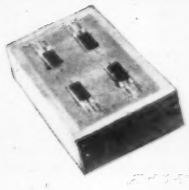
(c) Indication of the low velocities close to the ground. There are a number of theoretical problems, for which a plot of velocity versus height above the ground is desired and where low indications are desirable.

ACKNOWLEDGMENTS

are due to Mr. C. H. Colvin, Director of the Guggenheim School of Aeronautics, New York University, and Mr. Athelstan F. Spilhaus, Chairman, Department of Meteorology, New York University for many useful suggestions during the conduct of the tests. Thanks are due also to Professor Charles F. Brooks and Dr. S. P. Ferguson of the Blue Hill Meteorological Observatory, Harvard University, whose careful comments led to useful and necessary revisions throughout the article.

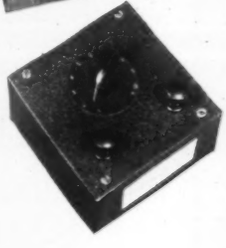
The object of most ... is made on materials, ... and structures is to determine ... magnitude, kind, and ... stresses—the amount of ... member or structure ... loading, twisting, vibration, ... distortion under specific conditions. Some of the many types of ... gages and auxiliary equipment needed in stress determination are the following:





RECORDING SCRATCH AND METALECTRIC STRAIN GAGES

are representative of the mechanical and electrical types of gages. Both gages are light-weight, simple, inexpensive, and reliable. The field of usefulness of these gages is almost unlimited. *Auxiliaries:* scratch gages, microscope for reading records, control box for static loads, amplifiers and recorders for dynamic loads.

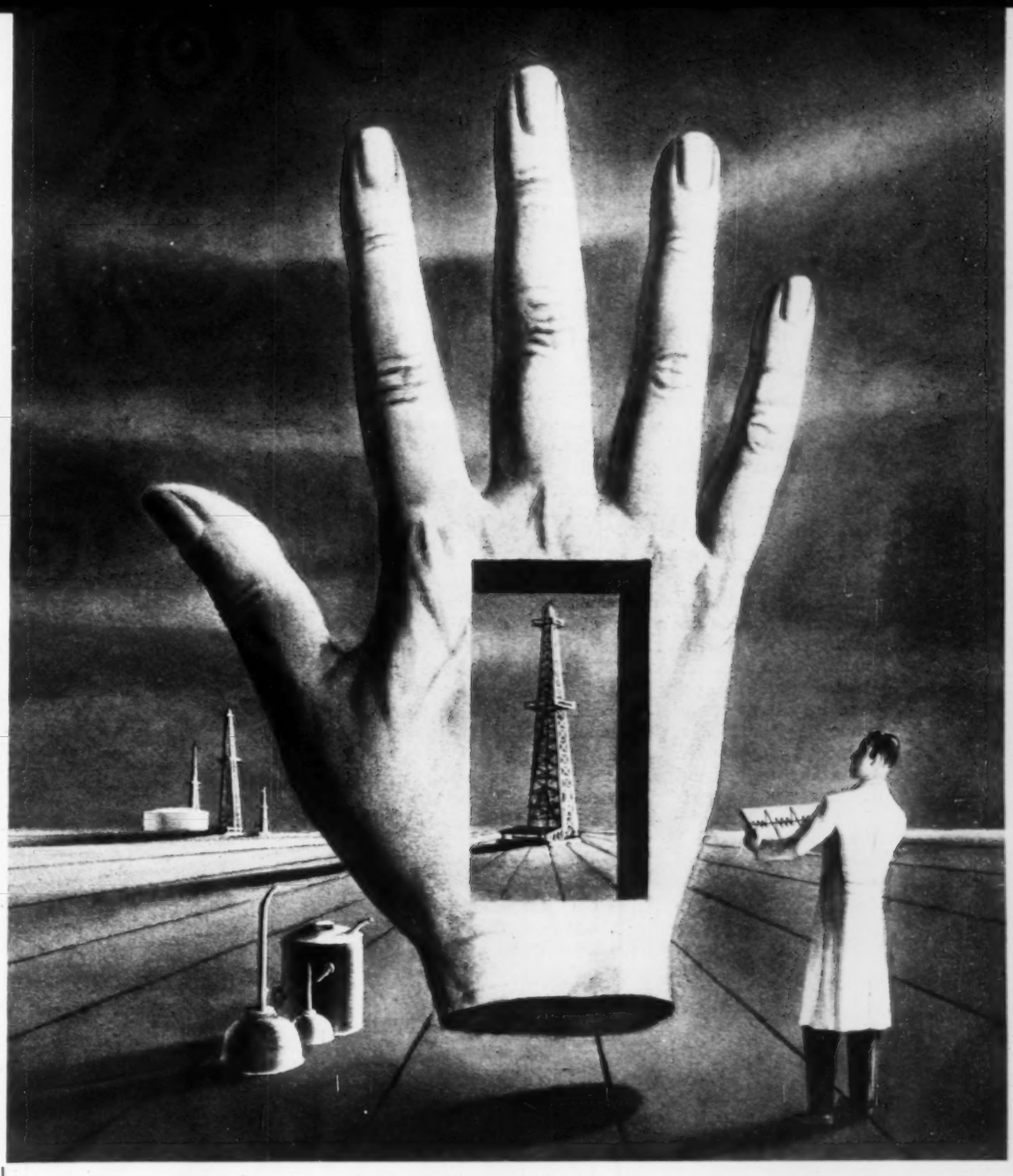


SLOW DYNAMIC CONTROL EQUIPMENT AND CALIBRATOR

Designed for use with electric and magnetic strain gages, static and slowly applied loads. Calibrator for instantaneous checking during dynamic testing of resistance type strain gages.

* * *

Other auxiliary testing equipment in this group: Spring and motor driven scratch gages; inductor telemeter; Stresscoat, a brittle lacquer for use in stress analysis; microscope and viewing equipment.



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Characteristics and Aircraft Applications of Wire Resistance Strain Gages

By A. V. de FOREST

Professor, Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

DURING the past two years more strain measurements have been made than in the previous century. On many engineering projects, from the massive penstocks of Boulder Dam to dirigibles and airplanes, designers needed measurements of local strain and went to great trouble and expense to secure them, but the instruments in use, or those especially invented for the various projects, did not permit of mass measurements. The wire gage is just the trick to provide a method of rapidly reading strains at widely separated points with any desired degree of sensitivity and accuracy.

It seems difficult to understand why the wire-resistance gage was so late in being invented. The need has long been evident, and the invention of strain gages is almost a hobby among instrumenticians. As it happened, the fundamental idea was arrived at by Simmons at the California Institute of Technology, and some notable improvements and applications were arrived at by Ruge at the Massachusetts Institute of Technology. This idea consisted in cementing down to a metal surface a small-diameter resistance wire, properly insulated, and measuring the change in length of the wire by measuring its change in resistance. The fact that many wires change resistance when strained elastically was already well known from Bridgman's work[1] on the measurement of hydrostatic pressures by means of coils of resistance wire. Carlson[2] had long used a strain gage for concrete in which the difference in tension, applied to two stretched coils of wire, was measured as a change in resistance. The final step lay in the recognition that a small-diameter wire (of the order of 0.001") could be so firmly held in a plastic cement, such as celluloid dissolved in acetone, glyptol, or Bakelite, that it could measure the strain applied to the metal to which it was bound, and respond accurately both in tension and compression, both statically and dynamically, both above and below the actual elastic limit of the measuring wire. The gage wire is held in cement which itself is not perfectly elastic, which has a low modulus, and a large temperature coefficient of expansion, and yet transmits strain so accurately that changes of load of 3 lbs./in.^{2} may be measured in steel, corresponding to 0.0000001 inch per inch.

The limitations appear to lie, not in the gage, but in the measuring equipment to read or record resistance changes. The original inventions of Simmons and Ruge have been taken over by the Baldwin-Southwark Division of the Baldwin Locomotive Works, through whom the gage has reached commercial requirements under the trade name of "SR-4 gages." These wire gages consist of a length of one-mil wire, looped back and forth over a $\frac{3}{4}$" length by $\frac{3}{16}$" wide, soldered at both ends to short copper lead wires, and the whole held in place by such a cement as Duco to a sheet of thin paper. In use, the paper is simply cemented with a sufficient layer of Duco to the desired spot and oriented in the direction in which the strain is to be measured. After two to ten hours drying period, depending on whether a hot-air blower is used, the gage is ready to use. DeKhotinsky cement is often used for quick applications and to permit removal and re-use. For dynamic measurements quick-drying cements are available which permit tests to be made within ten minutes. This size and construction is merely a convenient one and the resistance wire may be used in many sizes and arrangements including surfaces of double curvature.

The business end of the gage is the resistance wire and its method of support is the cement. Obviously the strain reaches the wire only through the medium of the cement, which carries a transverse as well as a longitudinal strain to the wire. This is obviously so in compression, where the wire may be brought back to its original dimensions and resistance after plastic deformation.

When a length of wire is elongated elastically, it is reduced in diameter by the amount corresponding to Poisson's ratio for that metal in the metallurgical structure which it happens to have. This factor has never been measured in small diameters, but in larger wire is about 0.3. An increase in length of 0.1% and a corresponding reduction in diameter would give a change in resistance of 0.17%. A convenient method of presenting strain sensitivity is to use a factor representing the ratio of unit change in resistance divided by unit change in length. A wire of 0.30 Poisson's ratio which changed resistance only by virtue of its geometry would have a factor of 1.7. Measurement of several available metals and alloy gives the strain sensitivity factors in Table I.

Table I

Wire	Strain Sensitivity	Stress in lbs./in.^{2} equivalent to 1° C. temp. change on steel
Manganin	0.47	—400.
Nickel	—12.1	—13,500. non linear
Nichrome	2.1	+2,100.
Phosphor Bronze	1.90	+7,800.
5% Iridium Platinum	5.1	+11,600.
Advance	2.1	±30. selected material
Copel	2.4	—200.
Monel	1.9	+8,000.
Iso Elastic	3.6	+5,000.

Annealing exerts a considerable influence on strain sensitivity, and the various factors in wire drawing undoubtedly are involved, but no research work has been done on this subject. It is certain, however, that small amounts of cold work such as strain beyond the elastic limit in handling, or by overloading the gage, have a negligible effect. Some alloy wire appears to show hysteresis between strain and resistance. Nickel has a strong negative sensitivity, in other words, decreases resistance as the wire is stretched, and is somewhat unstable.

Another requirement of suitable wire is that its temperature coefficient of resistance must be low for static measurements, otherwise a slight change in temperature would be interpreted as a change in strain. This temperature factor is more complicated than the ordinary temperature coefficient of resistance, as the wire in the applied gage is strained by the expansion and contraction of the metal to which it is cemented, and is influenced by this changing dimension and by that of the cement in which it is imbedded. While a compensation could be made by employing two wires in the gage, one of positive and the other of negative temperature coefficient, this solution has proved impractical. The customary method is to choose a wire for the gage which has only a small overall change due to the coefficient of expansion of the metal on which it is to be used and its own temperature coefficient of resistance, and to compensate by means of a similar gage, mounted on a similar metal at the same temperature but free of strain in the opposite arm of the measuring bridge.

This arrangement of a dummy gage may be easly ca-

[1] P. W. Bridgman. Theoretical Considerations on the Nature of Metallic Resistance, with Especial Regard to the Pressure Effects. *Physical Review*, Vol. 9, No. 4, Series 2, 1917, pages 269-289.

P. W. Bridgman. Effect of Tension on the Thermal and Electrical Conductivity of Metals. *Amer. Acad. Arts & Sci.*, Vol. 59, No. 6, 1923, pages 117-137.

[2] R. W. Carlson. Five Years' Improvement of the Electric Wire Strain Meter. *Engineering News Record*, Vol. 114, 1935, pages 696-697.

R. W. Carlson. Electric Strain Meter and Its Use in Measuring Internal Strains. *Proceedings ASTM*, Vol. 32, Part II, 1932, pages 793-801.

d for exact work by heating and cooling the part to ... the working gage is attached and the dummy over ... expected temperature range. In conducting careful ... asurements of this type it was found that the coefficient ... expansion of steel is extremely sensitive to cold work, ... the difference in expansion of the two sides of a cold-... rked bar can lead to confusing results. To compare the ... perature behavior of two gages precisely it is necessary ... mount them close together on the same side of an an-... aled bar. Such effects as these, however, are only impor-... t when dealing with strains of the order of one part in ... nillion, and where theories of elastic behavior are in-... olved, rather than problems of working loads or struc-... ural strength.

When dynamic loads only are involved the strain measurement is completed before a change in temperature can take place; and other wires than those of extremely low temperature coefficient are available. Of these the best with regard to high resistance, high and uniform strain sensitivity, freedom from hysteresis on loading and unloading, and important from a manufacturing point of view, ability to solder readily is the "Isoelastic," a 36% Ni, 8% Cr, 0.5% Mo wire. This alloy was developed by John Chatillon & Sons for precision springs of negligible temperature coefficient of elastic modulus. The high strain sensitivity is associated with another property of this alloy, namely its ability to endure a high degree of cold work. In the annealed state, the strain sensitivity is greatly lowered. This wire has an extremely low mechanical hysteresis, but this feature has no apparent relation to its excellent behavior as a gage wire, for other alloys showing greater mechanical hysteresis do not necessarily show hysteresis between strain and electrical resistance.

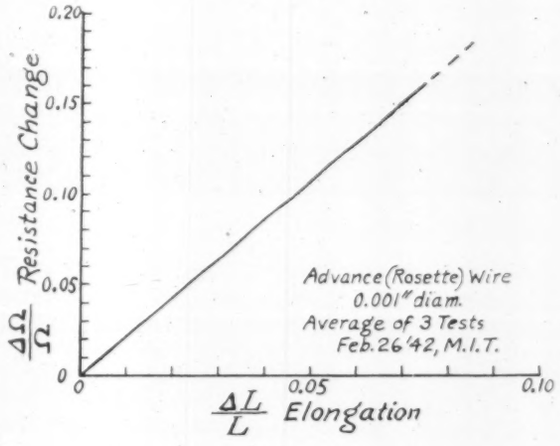

Fig. 1

Of the two alloys used commercially for their low temperature coefficient of resistance, namely Manganin and Constantan, the former has a low strain sensitivity although its low thermoelectric behavior against copper would be a great convenience. In general the Constantan type alloy is satisfactory, and the thermoelectric effect can be taken care of where necessary by special precautions. The simplest of these is to use alternating current for the measuring bridge. When working with a d-c. bridge at high sensitivity, the battery may be reversed and the bridge rebalanced. Among other alloys of low temperature coefficient of resistance, the 97.5% Au, 2.5% Cr. showed practically zero strain sensitivity: although the length was increased and the area decreased there was a negative strain sensitivity sufficient to maintain a constant resistance. Such a state of affairs is difficult to account for, but indicates a most desirable characteristic for standard resistances.

Fig. 1 shows a plot of strain versus resistance for a Constantan wire gage. It may be seen that there is no change in slope on passing through the yield point of the wire. The fact that strain sensitivity is substantially constant, and not a function of stress in the wire, is another unexplained but fortunate feature of this property.

APPLICATIONS OF GAGES

The most obvious use for wire gages is measuring local strains in complicated and redundant structures such as found in airplanes. In this field as many as 2000 gages are used in a single test under static loading by means of jacked-in loads. The loads themselves may conveniently be measured by gages on suitable sized weigh-bars between jack and structure. In such weighing problems, eccentricity of load can be completely eliminated by using gages on opposite diameters, or all the way around either tension or compression members. Such cases as measuring the total tension or compression of a bar subject to simultaneous bending may be simply handled, as also the bending or torsion component without the effect of longitudinal strain. A column in compression may be measured in bending only by subtracting the strains on opposite sides, when the two gages at these locations are connected in opposite arms of a bridge, or the total compression load measured by placing the gages in the same side. In many tests of compression members, the eccentricity of the load, rather than its total, is important.

By placing pairs of gages at 45° to the axis of a shaft, the total torsion may be measured without any disturbance from bending; or the thrust in a tail shaft may be measured without disturbance from the torque. For this measurement a high sensitivity may be needed for the bending component and a low one for the total compression. With suitable switchgear the bridge sensitivity may be altered for any individual measurement, and without readjustment of the zero position. By proper construction, thrust and torque dynamometers may be built in which the reading is independent of slip-ring resistance. Such a device is illustrated in Fig. 2.

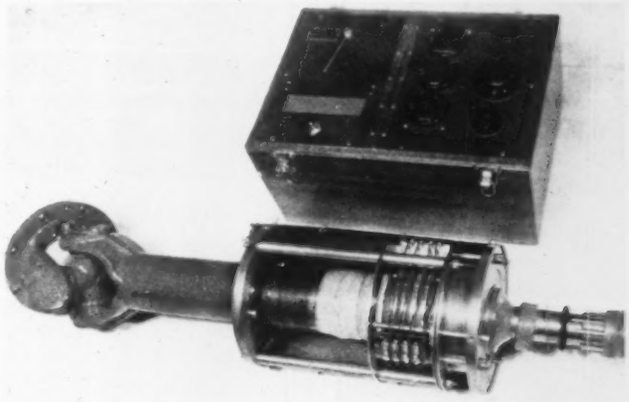

Fig. 2

Another useful modification of the gage is used for stress analysis where combined stress is present. Four wires crossing at 45°, or three wires at 60°, make it possible to calculate the elipse of stress over the area covered, usually a one-inch diameter. If a slightly larger area of uniform stress distribution is available, three standard gages at 60° may be used.

In many cases wire gages are convenient to measure displacements up to several tenths of an inch. This is easily done by placing gages on opposite sides of a cantilever spring and measuring the difference in stress on the two sides. The total motion of the spring end may be large, and measured at reduced sensitivity, but any particular portion of the whole scale may be greatly extended. Quite evidently this procedure is equivalent to using a weigh-bar carrying wire gages in series with a coil spring. By varying the design of the spring, deflections of any order of magnitude may be measured. Among other obvious applications are

Fig. 3. Records from Brush Crystal P
1 inch per second chart speed. See te

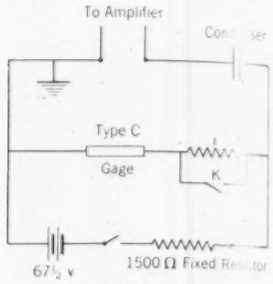

Fig. 4. Typical wiring diagram for dynamic testing.

measurements of pressure both in liquids or gases or those occurring in soils; accelerometers with high natural frequencies are readily constructed but require oscillographic recording. Slowly- or rapidly-changing loads, either transients or sustained vibrations, can be readily recorded by appropriate instruments.

METHODS OF MEASURING OR RECORDING STRAINS

All the customary methods for the measurement of resistance are available for measuring strain when properly handled. However, certain fundamental limitations must be born in mind. For static measurements, d-c. and a-c. galvanometers are readily available with sufficient sensitivity and sufficiently short periods to provide for the most exacting measurement. There is on the market a convenient form of bridge, known as the "SR-4 Control Box" and containing a d-c. galvanometer of the following characteristics: Resistance 50 ohms, period 2 seconds, sensitivity 0.04 microamps./mm. deflection on the scale. A multiple-reflection system is used for compactness. Either null or deflection method over a wide range of sensitivities is available. At the expense of sensitivity, shorter periods may be used. Occasionally 60-cycle a-c. bridges and galvanometers are convenient, particularly to avoid small thermal voltages generated at slip rings on torque dynamometers. For simplicity, long-time stability, and freedom from calibration difficulties, the absence of vacuum-tube amplification is often desirable and is obtainable only through the use of galvanometers. Electronic strain indicators and round-chart recorders are available as well as potentiometer recorders of the types used for pyrometry.

In many cases where numerous gages are to be measured in succession, switching gear of great variety has been devised. The problem is similar to that of connecting thermocouples to a central recorder, and sometimes the same equipment is used. However, when hundreds or even thousands of individual gages are used, as in the static testing of airplane structures, it may be worth while to build special motor-driven switches, and in some cases rapidly self-balancing bridges. Speeds of one reading per second are readily obtained, although for such rapid recording amplification is frequently resorted to. The whole system in such cases is sometimes sufficiently elaborate to call for an adequate electrical staff, and great circuit and mechanical simplicity is no longer necessary. For rapidly scanning a multitude of static or slowly-changing gages, an oscillograph is required—quite as much as when rapid fluctuations of load occur at a single gage. However, there is as yet no limit to the speed at which switching and recording can be accomplished if the need arises.

DYNAMIC STRAIN MEASUREMENTS

The problem of measuring rapidly-changing strains such as produced in the impact testing of metals was not solved until resistance strain gages of negligible mass were cemented over their full length to the strained metal. It was for this purpose that Clark at California Institute of Technology first used wire gages[3] and before that time integral carbon resistance gages were used by the author at the Massachusetts Institute of Technology[4] and for propeller stress measurements at the Hamilton Standard Propellers[5]. Many types of oscillographs are currently available, and the principal types only will be briefly listed here.

The need for low-frequency pen-and-ink recording of cardiographs and encephalographs led to highly developed instruments with a frequency range up to 120 c.p.s. The Brush pen driven by a temperature-regulated piezoelastic crystal is remarkably satisfactory with a maximum writing speed of 5" per second. Fig. 3 shows two records:

(a) Direct-connected through a potentiometer circuit given in Fig. 4. The minimum frequency for which this circuit is satisfactory usually depends on the amplifier used to drive the pen, but 1 cycle per second is easily reached.

(b) From a modulated 60-cycle bridge circuit which will respond to static conditions and frequencies up to 10 to 20 cycles at 1" per second record speed.

The great advantage of pen-and-ink recording is the instant availability of the record, so that tests may be carried out with certainty and conditions of one test may be used to guide the next without the delay of photographic development of records.

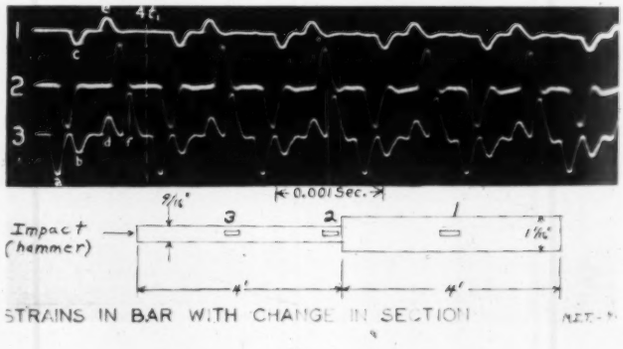

Fig. 5

Where higher speeds are required, the familiar moving-mirror or Duddell oscillographs are available. Multi-channel instruments of this type have been greatly improved due to their use in geophysical exploration. With speeds up to 200 c.p.s. sensitive movements with large mirrors are available, recording on bromide paper, and are used for flight tests in airplanes. The Miller and Continental are of this type and may be modified for higher frequencies up to a maximum of perhaps 2000 c.p.s. The Sperry-M.I.T. instru-

(Continued on page 136)

[3] D. S. Clark & G. Dätwyler, Stress-Strain Relations Under Tension Impact Loading, *Proceedings ASTM*, Vol. 38, Part II, 19 pages 98-106; discussion, 107-111.

[4] A. V. de Forest, The Measurement of Impact Strains, *Proceedings Intl. Congress for Applied Mechanics*, Sept. 12-16, 1938, pag 673-676.

[5] A. V. de Forest, Measurement of Propeller Stresses in Flig *Journal of the Aeronautical Sciences*, Vol. 4, No. 6, April 19 pages 227-232.

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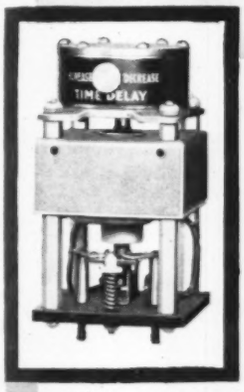

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A Precision Autographic Data-plotting Method

By FRED S. EASTMAN

Assoc. Professor of Aeronautical Eng'g; Wind Tunnel Supervisor; University of Washington, Seattle, Wash'n

IT may be unusual to describe a new method before its physical embodiment has been thoroughly tried and tested, but the writer is tempted by the thought that the rapid and precise plotting of data offers advantages of the utmost importance to testing and research laboratories throughout the country. If this is the case, coöperative effort could speed the process of converting the experimental device into a finished instrument, and in any case the following presentation may be helpful to those who desire complete records of all test data to be obtained quickly, accurately, and with reduced personnel.

PRINCIPAL CHARACTERISTICS

(1) Will plot data on standard cross-section paper 20" wide.
(2) Progress of the test can be watched and notes entered on the chart while in operation.
(3) Twenty seconds to change chart after each test.
(4) Any number of plotting pens may be provided.
(5) Accurate within 0.2% of chart width, and sensitive to less than 0.1%.
(6) Complete control of amplitude and relative position of the several plots.
(7) Variations from a mean value can be plotted to a large scale, showing changes of less than 0.01%.
(8) Plots harmonic fluctuations in excess of one cycle per second.
(9) Plots force, pressure, voltage, current, speed, temperature, etc., and their ratios, sums, or differences. (Auxiliary equipment required for some of these functions.)
(10) Data may be plotted against time or any other test variable.

GENERAL ARRANGEMENT

The plotting machine will consist of a flat table approximately 24" by 40", mounted on a stand so that it is a convenient height from the floor and accessible from all sides. A roll of cross-section paper will be mounted at one end and a receiving roll, in addition to a paper-cutting device, at the other end, so that completed records may be rolled up or cut off for immediate use. A clamping device will enable the operator to attach the paper quickly in its correct position. The several pens will be guided over the chart by tracks extending across the width of the table to a carriage, which is itself rolling on a longitudinal track beneath the table. The schematic diagram, Fig. 1, will help the reader to visualize this arrangement. Each pen is driven by a fine steel wire which passes over pulleys at each end of its track. These pen tracks will be the only obstructions to clear view of the chart. By depressing a lever, the operator can lower the table enough to withdraw the chart from contact with the pens at any time he chooses. In this way those portions of a test which are of no value may be omitted from the record, and the pens can be returned to their starting positions without marking on the chart.

Accurate positioning of each pen on the chart is accomplished in a manner quite similar to that employed in the usual self-balancing potentiometer type recorder, but more than ten times the usual voltage is impressed across the slide-wire. This increased voltage obviates the need of maintaining an extremely precise voltage balance, thereby tending to increase accuracy and reliability. For example, it is possible to design the slide-wire for a drop of 100 volts, in which case the potentiometer would have to be out of balance at least 100 millivolts to cause a 0.1% error in position. The experimental slide-wire shown in Fig. 2 is composed of 1000 accurately spaced turns of wire wound on a tube about 2" in diameter. Surprisingly little difficulty was found in making it sufficiently linear to insure that the balance point would not be in error more than one turn out of the 1000 total.

Current is supplied to the slide-wire by electromagnetic balance *A*, in Fig. 1. Since this device was described by the author in the October 1941 issue of *Instruments**, suffice it to say that it maintains the current precisely proportional to whatever force may be applied to *A*. Therefore, any one of a series of chosen reference voltages may be established across the slide-wire by merely applying appropriate weights to *A*. The variable to be measured is applied to another electromagnetic balance, *B*, which supplies corresponding current to resistance *C*. The control circuit, *D*, causes the slide-wire to move until it picks off a voltage which balances the drop across *C*. Switch *E* selects the zero position, and resistance *F* is used to move the zero position some distance off the chart in case it is desired to plot variations from a relatively large mean value. Switch *G* adjusts the amplitude of the plotted curve, and can provide definite multipliers from 1 to 100 and possibly up to 1000. Variable resistance *H* bypasses a small part of the current from *A* to compensate for expansion and contraction of the chart.

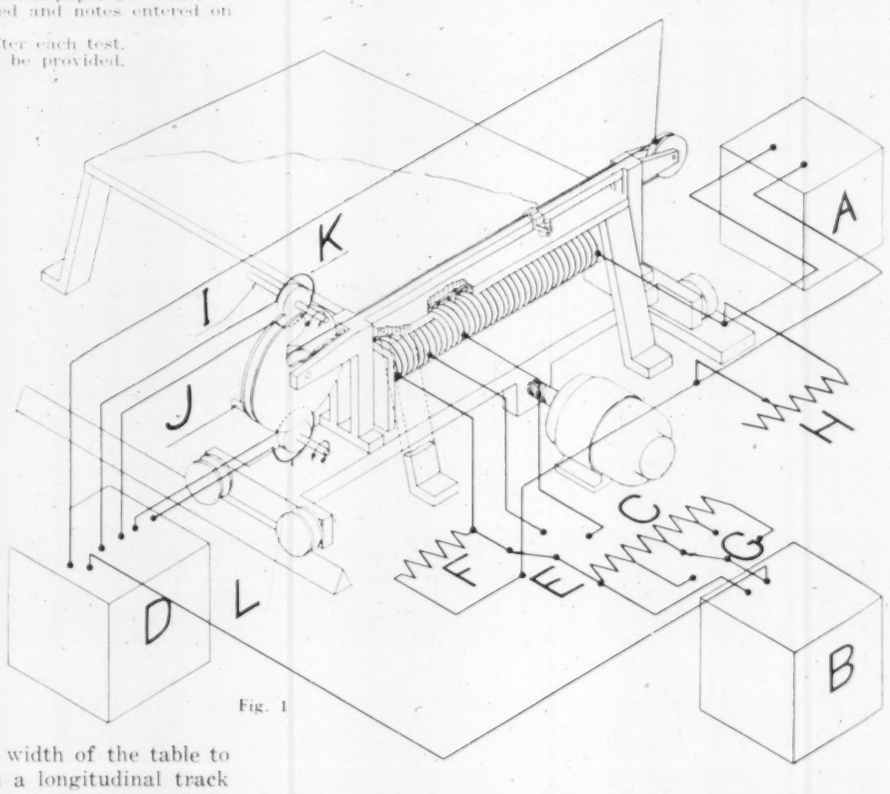

Fig. 1

THE CONTROL CIRCUIT

The function of the control circuit, *D*, is to detect any unbalance between the voltage picked off by the sliding contact and the drop across *C*. In addition, it must be able to move the contact toward the balance position when necessary. The high voltage used across the slide-wire adds to the feasibility of using direct vacuum-tube amplification for this purpose. This type of control needs no delicate

*Fred S. Eastman. The Electromagnetic Balance—A High-Precision Measurement and Control Device. *Instruments*, Vol. 14, 1941, pages 284-285, 310-311.

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galvanometer or relays and it paves the way to higher speed of response than is possible by other means. The experimental slide-wire unit shown in Fig. 2 has been operated successfully by using a d-c. amplifier controlling a reversible d-c. motor which drives the contact by means of a screw, but it was feared that the desired degree of reliability could not be obtained because of the tendency for d-c. amplifiers to drift. This would cause the contact to seek a position slightly off from the true balance position. On the other hand, if the drop across the slide-wire is kept above 40 volts, it is not difficult to confine this error within the desired limits.

The desire to make the plotting machine operate satisfactorily when less than 5 volts is impressed across the slide-wire led to experiments with various means of converting the small d-c. input to a.c. and then amplifying as much as may be necessary to control the power tubes. It is too early to report on the results of these experiments except to say that there is little doubt that the job can be done, but that the complexity of the equipment may prove to be somewhat objectionable. In this respect, it is reassuring to note that the Brown Instrument Co. is using direct vacuum-tube control on its new circular chart potentiometer, and that the control circuit of this instrument is compact and has greater sensitivity than would be required for this plotting machine.

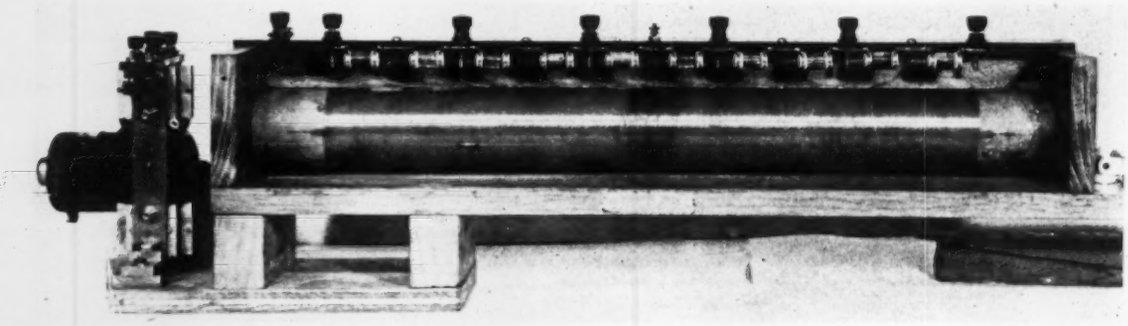


Fig. 2

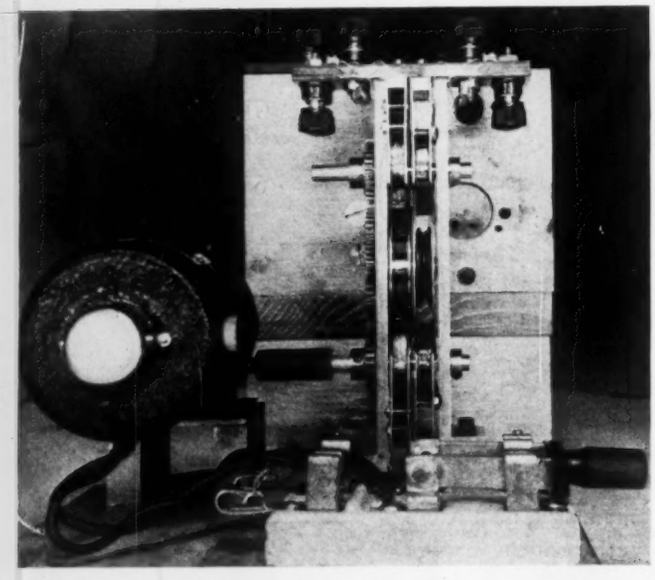


Fig. 3

PEN DRIVE UNIT

Experiments with various types of motors directly connected to a screw driving the pen and contactor indicated that the inertia of the rotating parts was so great that full advantage of the quick control circuit could not be realized. Friction drives having magnetically-operated clutches gave promising results, leading finally to the device shown in Figs. 2 and 3. This can be understood more readily by referring again to Fig. 1. The two shafts *I* and *J* are driven at constant speed but in opposite directions. The pen and sliding contactor are attached to a fine steel wire passing around pulleys at each end of the slide-wire. Two iron disks are keyed to the driving pulley shaft in such a way that they can wabble slightly on the shaft. When coil *K* is energized, the magnetic flux causes the plates to pinch the ends of an iron collar attached to shaft *I* and extending through coil *K*; but when coil *L* is energized, the plates are drawn away from this collar and into contact with a similar one on shaft *J*, thus reversing the pulley. The weight of the accelerated parts is so small, and the friction force is so large, that starting and stopping of the pen and contactor are practically instantaneous. From a speed of 2" per second, the contactor appears to stop dead, at the correct balance position, and it is believed that speeds in excess of 10" per second can be used without sacrificing accuracy if the two-speed drive illustrated in Fig. 3 can be used to full advantage. This makes use of two pairs of iron disks on the pulley shaft, one being of greater diameter than the other and engaging a correspondingly smaller diameter iron collar. A four-to-one speed change is easily obtained in this manner without adding appreciably to the cost of the device. Four controlling coils are used but only the two for high speed, or the two for low speed, are used at one time. The high-speed drive goes into action only when the low speed is inadequate to maintain balance. Notice that this type of drive is well suited to the addition of many pens staggered one inch along the chart, each being driven from the same two constant-speed shafts.

CARRIAGE DRIVE

Normally the carriage will be driven by a synchronous motor provided with change gears to give speeds ranging from one inch per second to one inch per minute, but by changing to a Selsyn motor drive the movement can be linked to any one of the test variables which is capable of driving a Selsyn device. Consideration has been given to the possibility of driving the carriage in a manner similar to that employed for the individual pens. In this way, movement of the carriage could be an accurate measure of any of the variables which can be plotted by the pens, and any pair of variables could be plotted one against the other.

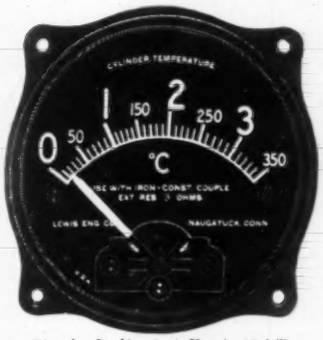
When plotting test data against time, it will be necessary to select the carriage speed so that the complete test should occupy only about 75% of the chart length, leaving the remainder for unforeseen delays. In the event that the carriage should actually reach the end of the chart, an automatic reversing device will cause the carriage to move back over the same chart. Thus no data can be lost, although the double record may be more difficult to read.

PLOTTING WIND TUNNEL MODEL DATA

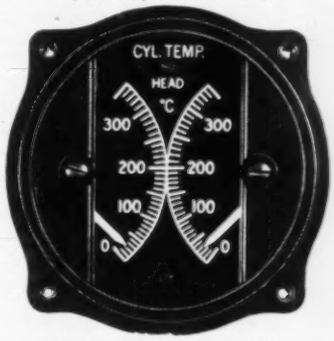
The process of obtaining wind-tunnel model data usually requires that a series of readings be taken of the air forces acting on a model, as the latter is moved into different positions relative to the air stream. For any position of the model, all the variables vary approximately in proportion to the square of the air speed, and since the latter

ENGINE CYLINDER TEMPERATURE INDICATORS—THERMOCOUPLE TYPE

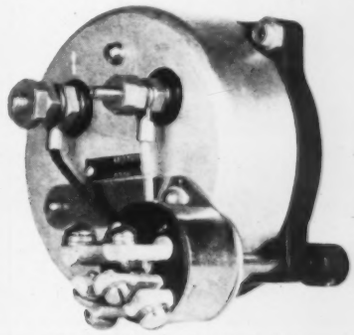
(Write for Bulletin 1-2)



Single Indicator Part 17AT



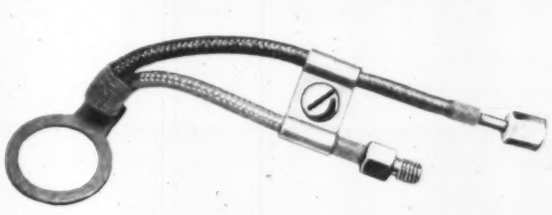
Dual Indicator Part 96AT

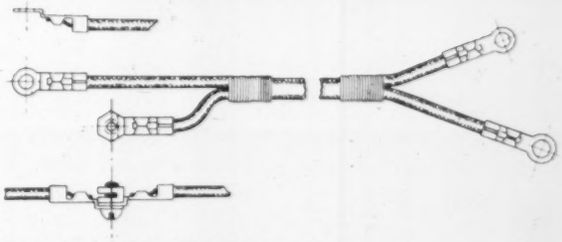


Part 17AT with 98 Switch

Lewis cylinder temperature indicators have been used for many years in training, combat, military and commercial transport, and privately operated aircraft. Their quality is affirmed by all.

THERMOCOUPLES *(Write for Bulletins)* **EXTENSION LEADS**





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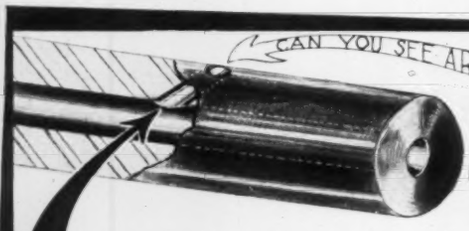

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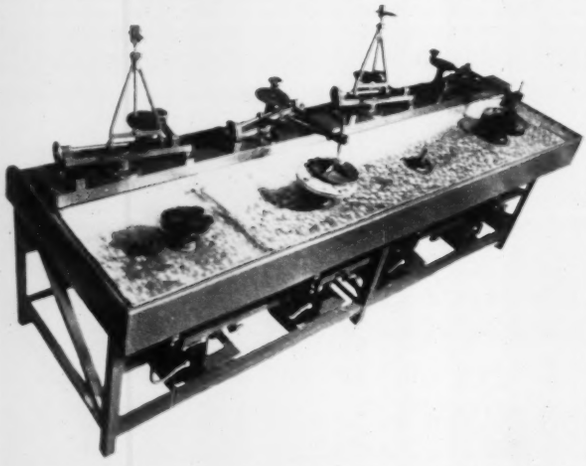

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cannot be maintained at precisely the desired value, accurate measurements are obtained by taking readings only during short intervals while the air speed remains correct. The plotting machine will record the percent error due to changes in air speed along with the other test data, so that minor corrections can be made afterwards if necessary. If preferred, the operator can depress the table, thus separating the pens from the chart, during such time as the air speed is incorrect.

Neither of the above procedures utilizes the plotting machine to its best advantage. To illustrate what is probably a revolutionary method of obtaining wind tunnel data, suppose that the weight applied to balance *A*, in Fig. 1, is replaced by a force which is proportional to the square of the air speed.* The result is that when the air speed diminishes slightly, both the slide-wire voltage and the drop across resistance *C* will diminish correspondingly. Consequently, the pens will not move. In other words, the curves plotted will represent the ratios of each of the variables, to some reference magnitude which varies with the square of the air speed. Those familiar with wind tunnel testing will observe that this amounts to plotting aerodynamic coefficients directly, instead of computing them from the measured forces and the air speed. The great advantage of this method is that every point on the curves obtained is truly indicative of the information desired, even though the air speed may have deviated slightly from time to time. Moreover, once the amplitude adjustments have been made to suit the dimensions of the model, no further adjustments need be made regardless of the air speed used. To extend this advantage over a wide range of air speeds, however, the plotting machine must operate satisfactorily with low voltage as well as with high voltage across the slide-wire.

PLOTTING TRANSIENT CONDITIONS

The air loads are never absolutely steady, and there are times when important information is lost because the common methods of taking readings yield only average values. For example, erratic changes in air load may indicate a condition of unstable air flow which should be corrected before further tests are made. The plotting machine will have sufficiently rapid response to show the approximate magnitude and character of such variations, thereby offering a clue to the solution of the problem. More than this, it would permit detailed study of various transient loads such as the stalling of a wing or the effect of sudden movement of the model. It is too early to predict how well the plotting machine can follow rapid transients, but if a pen speed of 10" per second can be obtained, small-amplitude plots of variations taking place several times per second may be reproduced on the chart with sufficient accuracy.

PLOTTING PRESSURE PROFILES

A pressure profile obtained from any number of pressure tubes can be plotted with one pen by recording the pressure from each of the tubes in proper succession. If the pressure in each tube is recorded while the carriage progresses $\frac{1}{2}$", the pressure profile from sixty different tubes will cover 30" of the chart. The rapid response of the pen will give almost instantaneous transition from one reading to the next, and errors due to small changes in air speed can be eliminated as suggested above. In this way, the 60-tube profile could be obtained in less than two minutes, and the use of more pens would reduce the time correspondingly.

MISCELLANEOUS DATA PLOTTING

The plotting machine is not limited to recording the more common kinds of wind tunnel data. In fact it is readily adapted to plotting anything that can be converted into a mechanical force or an electrical current. Suppose it is desired to plot temperature by the use of a thermocouple. The thermocouple voltage is too small to measure directly

*The pressure balance described in the October issue of *Instruments* will replace balance *A*.

the high voltage potentiometer, but a corresponding ... can be applied electrically to balance B. This is done ... passing the current from the thermocouple through a ... cial coil on the balance provided for the purpose of con... ting a small current into a measurable force. Thus the ... ntiometer operates as usual, the only difference being ... t the force produced by the few microwatts will be ex... mely small and the balance must be designed to take ... into account.

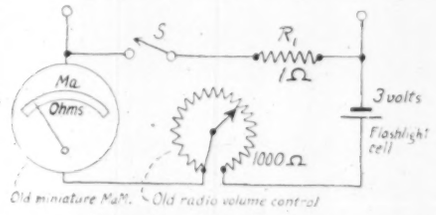
It is hoped that these few examples of the possible uses ... this many-purpose plotting machine will serve to sug... t many others in which a real advantage can be gained ... the continuous record, rapid response, and high precision ... ered by this device.

Ingeniously Assembled Tester

To the Editor of *Instruments*:

The small and simple device herein described has proved quite helpful in my work and may prove of interest to others in the field. I assembled it from materials and parts on hand and fitted it into an old Bakelite standard-cell case, which makes it pocket-size.

In general it is nothing more than a circuit or continuity tester roughly calibrated in ohms directly on the instrument



scale. However it has the additional feature of making a variable millivoltage available at the terminals by cutting in the one-ohm resistor R_1 by switch S. The instrument—an inexpensive one—just happened to have the range of 0-25 milliamperes. By Ohm's law it can readily be seen that by varying the current through R_1 from zero to 25 milliamperes we have 0 to 25 millivolts appearing across R_1 and at the terminals. In other words it is direct-reading in millivolts output on the milliampere scale.

This tester has been especially helpful in tracing out thermocouple lead wires on experimental units.

PHILIP W. DEWEY
Instrument Mechanic
Standard Oil Co. (Indiana)

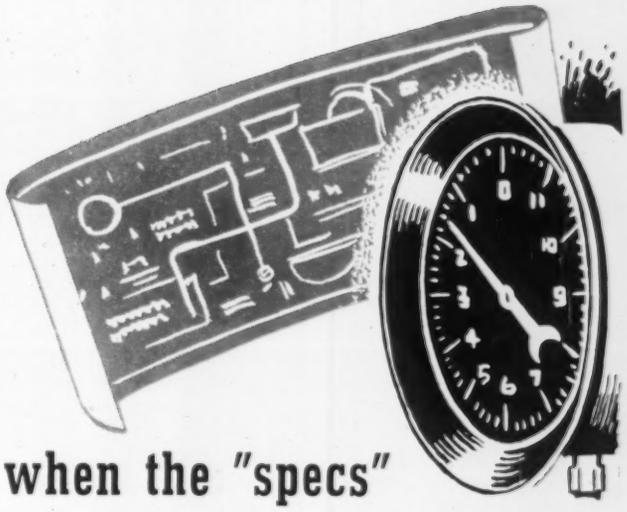
Whiting, Indiana,
March 4, 1942

X-ray Inspection of Rubber Heels

With millions of rubber heels going to our military forces, the necessity for rigid inspection has become even more important. One of the conditions found in defective heels in the past has been occasional misplacement of one of the steel washers which are imbedded in the rubber heel and firmly hold the nails which attach the heel to the shoe. Misplacement means that when a nail is driven in, it will have nothing but rubber to hold it in an upright position. Even the most rigid manufacturing controls used up to the present were unable to prevent some of the misplaced washers.

To remedy this and make certain that every washer is in its allotted place, The B. F. Goodrich Company has installed new type X-ray machines in its principal rubber heel manufacturing plant.

The stream of rubber heels which comes from the vulcanizers passes through these machines, at each of which sit keen-eyed, alert girls, their eyes fixed on the shadows of the moving heels as the conveyor belt carries them under the X-ray eye. If a single washer is even minutely out of place, so the nail will not go cleanly through it, the girl detects it on the shadowgraph screen and the heel is discarded. The proportion of rejects is small but the operation of the X-ray machine is one more step in product perfection before it reaches the consumer.



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How a Great Airline Keeps Its Vital Aircraft Instruments Clean

By ROBERT K. FARNHAM

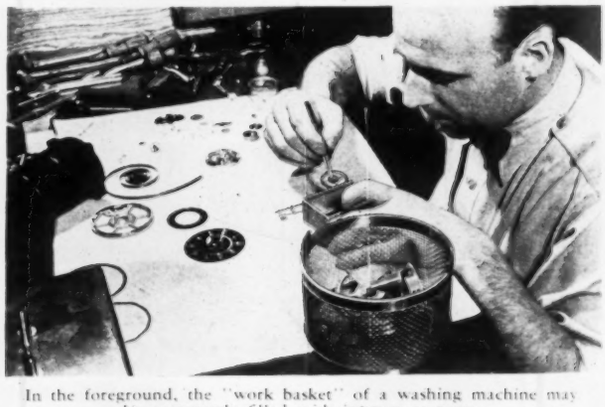
Field Representative, New York District, The Instruments Publishing Co.

IT is not necessary to draw complicated comparisons in order to trace the course of instrument cleaning. Parts may be cleaned either by hand as they have been for years, or by the new mechanical process. There is something to be said for both procedures, but it is interesting to note how steadfastly those who have seen it work are switching to machine cleaning.

Possibly the most important factor influencing the adoption of mechanical cleaning is the need for faster production. At no time in the history of our country has the need for speed been greater—especially in the aviation field. With plants working on 24-hour seven-day-a-week schedules, manual cleaning leaves much to be desired when quantity production is the watchword. Until recently, when an instrument was reconditioned by hand every element comprising its mechanism had to be carefully dipped in a cleaning solution, brushed and dried in sawdust. It took at least thirty minutes, and sometimes more than ninety minutes, to take down, clean and reassemble the parts.

The parts of a disassembled instrument.

An aircraft instrument is somewhat like a watch, and watchmakers have for years been cleaning the finest watches quickly and economically, using watch cleaning machines and solutions. Sales reports from the makers of this equipment indicate that their business has increased substantially. Watch cleaning machines apparently are doing a good job.



In the foreground, the "work basket" of a washing machine may be seen partly filled with instrument parts.

News of this mechanical method spread. A utility company heard about it next. They needed a larger unit to clean meters, gages and similar devices. One was specially built for them. The usable area of the work basket of this new machine is $5\frac{1}{2}$" I.D. by $3\frac{3}{8}$" deep. It worked better than they had expected it would. They placed additional orders. Today, batteries of these machines have been in

(Continued on page 15)

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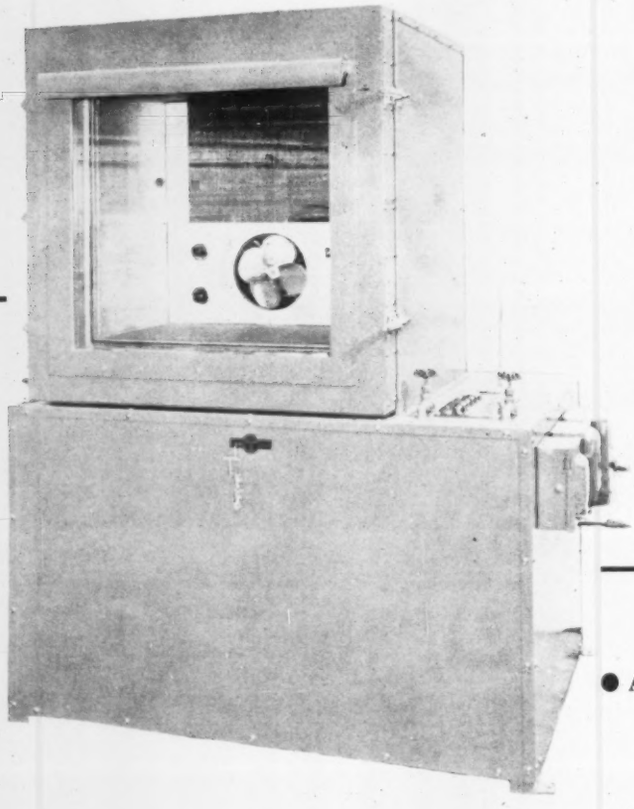

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High-altitude Test and Calibration Equipment

By ERWIN LODWIG

Chief Engineer, Mobile Refrigeration, Inc., New York City

DURING the past year great strides have been made in the development of high-altitude test and calibration chambers and, while in some cases cotual tanks are employed, mechanical equipment is becoming standardized in the industry because of its superiority. The company with which the writer is associated undertook the solution of this problem approximately a year and a half ago. Today a production line is turning out the standard commercial units described in this article; and a laboratory is creating specialized instruments for the Army and the Navy as well as for instrument manufacturers.

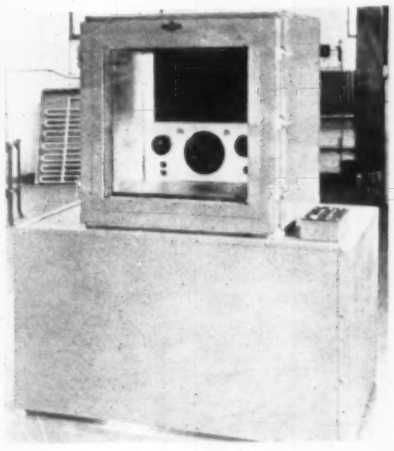

Fig. 1

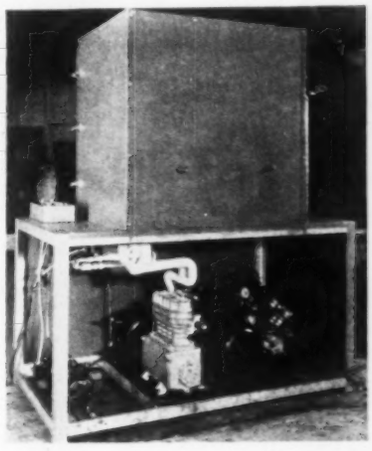

Fig. 2

Fig. 3

In solving this problem, it was necessary to obtain accurate data on the conditions to be achieved, to ascertain the probable rates of climb of newly designed aircraft, as well as to discover the true meaning of "flight similitude." The standard atmosphere tables and data furnished considerable information. However, the altitude tables thus obtained relied on empirical formulae and did not take into consideration flight-recorded temperature as low as -92°F. In the beginning, instrument calibration was considered satisfactory at -25°F.

Gradually, manufacturers requested equipment the temperature of which could be reduced to -40°F. Standard equipment has been developed for test points as low as -100°F. and vacuum to 0.1" Hg absolute.

At first, ±5°F. was considered excellent tolerance for control of the temperature within the chambers. At present, requirements to ±0.1°F. are experienced and ±2°F. is standard over the entire temperature range. Numerous specifications involving unusual weather conditions to be obtained within the chamber range from sandstorms at -76°F. to tropical humidities at 158°F. These unusual requests are being met but the industry seems to be settling down to a standard form of the apparatus shown in Fig. 1. This chamber consists of a steel casing, strong enough to withstand a full vacuum, surrounded by sheet steel insulation with air spaces between. The cabinet is equipped with a tempered glass observation door to withstand vacuum conditions and several layers of glass separated by air spaces as thermal insulation. This cabinet is lighted by an exterior reflector which supplies 30 foot-candles at the center of the test space. It is mounted on an equipment cabinet (see Fig. 2) which contains 2- or 3-stage mechanical refrigeration equipment, vacuum pump, heat interchangers and control equipment.

While numerous sizes have been constructed, a standard A&N instrument rack set the 24" × 24" × 16" free space dimensions of the larger chamber and the Weather Bureau radiosondes set the 12" × 12" × 12" clear space of the smaller unit shown in Fig. 3.

The side plates of the chambers have mounted on them, as standard equipment, manometer connections and vacuum-tight connector pads having as many as thirty electric connections rated at 220 volts; while specialized pads with connectors will carry voltages up to 1000 volts at 1" Hg. Numerous special drives for tachometers, generators, fuel pumps, super-chargers and all manner of instruments have been provided as auxiliary equipment.

After the equipment had been perfected, insofar as reaching these extremely low temperatures, the problem of flight similitude, or pull-down time, again came to the front. One manufacturer required that the temperature should be reduced from room temperature to -76° F. in an hour and fifteen minutes along a straight line curve. The next would complain that this did not follow the curve taken from the standard atmosphere tables, while a third demanded that a curve based on a maximum and minimum rate of pull-down along a flat parabola be followed accurately. Records of outside air temperature in both planes and radiosondes showed conditions over central Texas, where the ground temperature was 85°F., as follows:

Alt. (1000 ft.)	10	15	18	20	22	35
Temp. (°F.)	-10	-22	-8	-54	-49	-92

Wide fluctuations in temperature are encountered and a straight line or parabolic relationship of altitude to temperature does not offer conditions of actual flight. However, the curve selected by the writer closely satisfies all requirements. See Fig. 4.

Several units have been constructed with various means for approximating a multitude of flight conditions. Among these was a system involving a motor-driven shaft on which could be mounted cams, cut from actual balloon flight records, which controlled, from minute to minute, the rate of refrigeration in the chamber. Others were developed, which were controlled by a series of thermostats with mechanical selector switches. In the final analysis, for orderly test and calibration purposes, the curve adopted by the company with which the writer is associated was found to be economical, accurate and effective. With the present control

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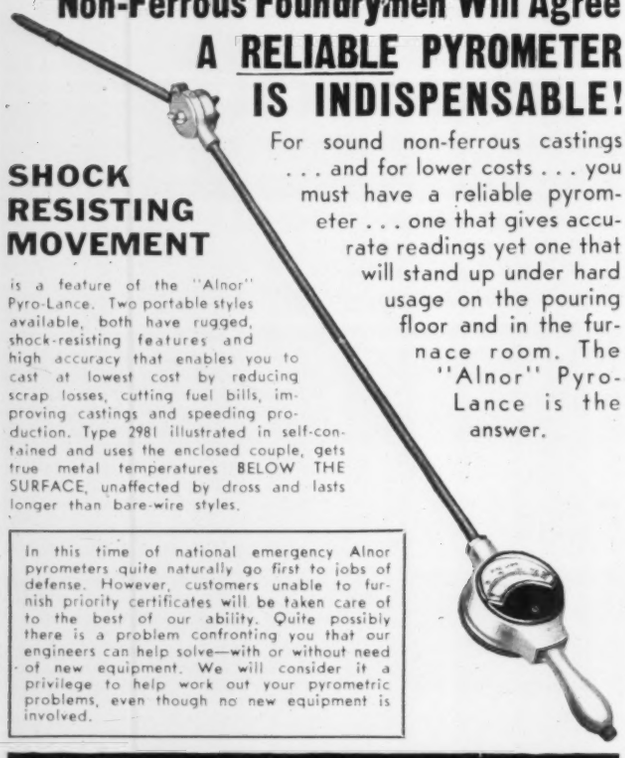

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is a feature of the "Alnor" Pyro-Lance. Two portable styles available, both have rugged, shock-resisting features and high accuracy that enables you to cast at lowest cost by reducing scrap losses, cutting fuel bills, improving castings and speeding production. Type 2981 illustrated in self-contained and uses the enclosed couple, gets true metal temperatures BELOW THE SURFACE, unaffected by dross and lasts longer than bare-wire styles.

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ASHLAND, MASSACHUSETTS

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system, required test points along the curve may be selected in advance of the test run and maintained within 2°.

This type of equipment is not only in use for testing finished instruments, but is being successfully used in checking expansion and contraction of linkage parts, the characteristics of springs, durability of diaphragms made of synthetics or metal, wear tests, humidity absorption tests, electronic and frequency values in communication, characteristics of all manner of electric equipment; and others too numerous to mention here.

Among the less-understood characteristics now being observed and coded as data are such problems as:

Crystallization points of all materials.
The effect of sub-atmospheric temperatures and rarefied air on materials.
The loss of insulating qualities of rubber and plastic conduit.
The pour points of lubricants in relationship to their full temperature range of effectiveness.
Degassing of materials under conditions of sub-zero temperature and sub-atmospheric pressures.

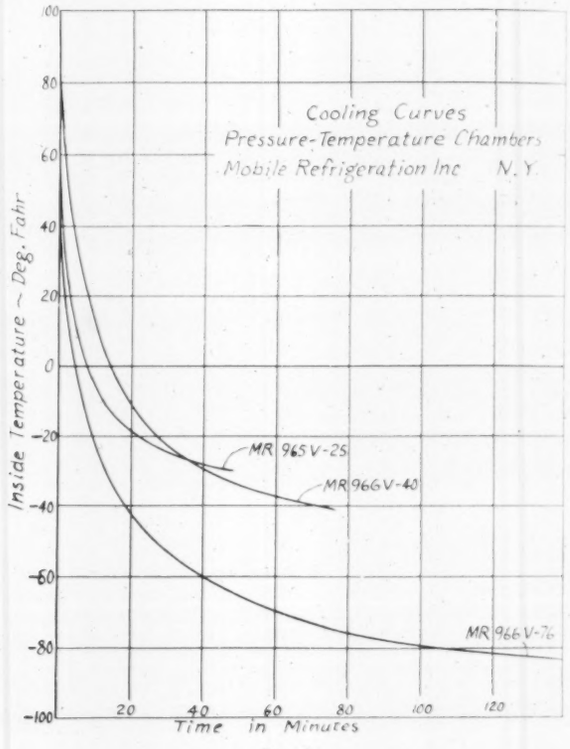

Fig. 4

These are, on the whole, research problems. From a pure production standpoint there are many testing, correcting and calibration procedures which require cold and vacuum to various degrees, for instance:

Aircraft and research instrument production-testing and calibration; maintenance and usage correction and repair tests for instruments and all other aircraft accessories and materials; manifold and mounting fatigue factors; fabric distortion index determination; hydraulic lock checks; seal and closure tests; radiomatic affectation; load and capacity ratings; static load and unload tests; heat-treatment of aluminum alloys and certain plastics; shrink-fitting of machined surfaces; cold-curing of raw materials; rivet cooling; checking of response lag in indicating and recording instruments.

From the data obtained in these small chambers our company has been able to develop high-altitude chambers as large as 3500 cu. ft. having a low temperature of –100° F. and capable of reaching pressures to 0.5" Hg abs. in which training equipment, entire fuselages, and personnel, can be studied.

Positive controlled mechanical refrigeration has become the answer in forecasting the safety and effectiveness of wartime aircraft and armament equipment, without the catastrophes which await the test pilot in the upper altitudes in untested ships. It is hoped that the information derived from this equipment during the war will lead to more effective and economical peace-time flying.

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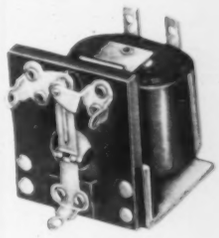


Series 10

GUIDE TO KURMAN RELAY SPECIFICATIONS

SERIES	RATED INPUT DC WATTS	RATED INPUT AC V.A.	AMPERE CONTACT RATING	WEIGHT OUNCES	DIMENSIONS INCHES
5	2.5	8.0	15	7 1/2	3x2 1/4 x2 1/8
10	.35	—	.5	1 1/2	1 5/8 x1x1 1/8
11	.80	4.4	1	2 1/4	1 3/4 x1 1/8 x1 3/4
12	.018	—	.25	1 1/2	1 3/4 x1 1/8 x1 1/8
15	2.0	6.0	1	3 3/4	1 3/4 x1 1/8 x1 3/4
25	2.0	4.0	10	4	2 1/16 x1 3/8 x1 1/8
200	.014	.36	3	6 3/4	2 3/8 x2 3/8 x1 3/8
300	.014	.36	3	6 3/4	2 3/8 x2 3/8 x1 3/8

NOTES

I. All current contact ratings are in amperes at 110 volts 60 cycle AC.

II. Dielectric strength of 1500 volts exists between contacts and ground in Series 10, 11, 15.

III. Insulated armature, shown on Series 300, is recommended for high frequency transfer. This feature may be specified for Series 200.

IV. Ferronickel alloy is used in the magnetic circuits for Series 10, 12, 200, 300.

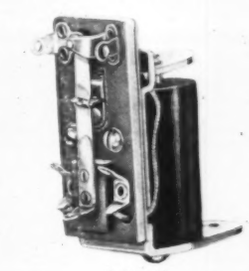
V. Ceramic insulation in Series 25 permits high frequency transfer with low capacitive leakage.

VI. Dampened armature action in Series 25 is designed to reduce contact bounce after initial pull down.

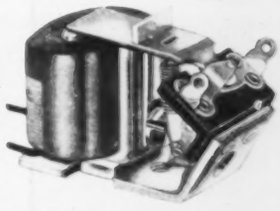
VII. Rated watts represents practical minimum input at standard adjustments.

VIII. AC relays have approximately .5 power factor.

IX. List prices vary with specific voltage and insulation requirements.

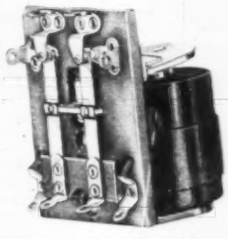


Series 11

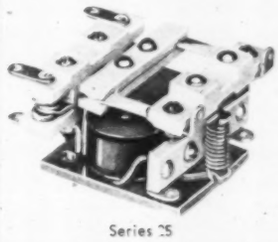


Series 12

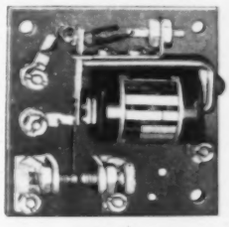
RELAYS DESIGNED TO MEET YOUR SPECIFICATIONS



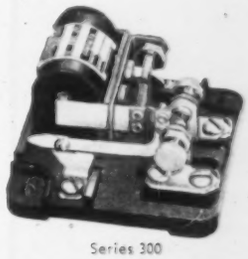
Series 15



Series 25



Series 200



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By JAMES SPENCER

Foreman, Instrument and Relay Testing, Westinghouse Elec. & Mfg. Co., Newark, N. J.

CHAPTER VI
FREQUENCY METERS

The frequency of an alternating current is the number of cycles (or complete double-reversals of direction) per unit of time. The standard way of expressing frequency is in *cycles per second*. The correct abbreviation is c.p.s. However, every worker in electricity knows—or should know—that the time unit is the second, so that it is customary to leave out the words "per second" and use such expressions as "a 60-cycle line."

The methods of ascertaining circuit frequencies are divided into (1) mechanical and (2) electrical frequency meters. In this chapter we shall discuss the care and maintenance of the vibrating-reed (mechanical) type; and of various electrical types as follows: the induction type, the electrodynamic or bridge type, the movable-iron type, and the resonant circuit type.

To convert revolutions per minute into cycles per second, apply the formula $PS \div 120 = F$ where P is the number of poles in the machine, S is the speed in revolutions per minute and 120 (alternations per second) is the constant used to change "Alternations per minute" to "Cycles per second."

In cases where there is a question as to the number of poles in a machine, check the name-plate reading and apply the above formula in reverse, that is, P=frequency in cycles per second $\times$ 120 = revolutions per minute. Example, assume the name-plate reading to be 60 cycles at 1200 r.p.m. Applying the formula, we would have

$$P = 60 \times 120 \div 1200 \quad \text{or 6 poles.}$$

TESTING—GENERAL

The circuit to which the frequency meter is connected for making calibration checks or adjustments, should be one whose frequency can be varied. This may be done on the circuit to which the instrument is installed if it is convenient to check the speed of the alternator supplying the circuit. If the generator supplying the circuit is not located conveniently for making this test, the instrument should be removed from its mounting and connected to the circuit of a variable-speed alternator, inverted rotary converter or some such machine whose speed may be varied. The scale points may be checked by comparison with a standard frequency meter of known accuracy as the speed of the machine is changed, or with a tachometer, or with a revolution counter and watch. The speed of the machine may be found by inserting the shaft of the tachometer or revolution counter in the V-shaped center mark in the end of the generator shaft. In the case of the tachometer, the speed may be had directly, but with the revolution counter and watch, the number of revolutions must be counted in the space of one minute.

*Notes on Tachometers, Revolution Counters, etc.**

If a tachometer is used, it should be an extreme-precision instrument—one which can be easily read to 2 r.p.m. at 1200 r.p.m. (or to 6 r.p.m. at 3600 r.p.m.) and which was sold with a certificate stating that its error when properly used does not exceed 2 or 3 r.p.m. at 1200 r.p.m. (or 8 or 10 r.p.m. at 3600 r.p.m.).

The reason for this recommendation is made obvious by Fig. 1 which is two sketches (not drawings of actual instruments) showing an "ordinary" tachometer compared with an "ordinary" frequency meter. It can be seen at first glance that the tachometer is one designed to be read easily from a distance, while the frequency meter—by contrast—has the appearance of a precision instrument.

On second glance it will be seen that the tachometer has a 360° or full-circle scale, of which only a quarter (or quadrant) is shown. The scale range is 0 to 4000 r.p.m. The scale dial is so arranged that the zero point is shifted 146° counterclockwise to bring the 3600-r.p.m. graduation at the top for convenience in checking electrical machines rotating at this speed (one of the modern standard speeds). The scale length (circumference) is 12". The scale interval per 100 r.p.m. is 12 ÷ 40 or 0.30".

The frequency meter sketched in Fig. 1 has a scale with a range extending from 57.5 to 62.5 cycles. This is known as a *suppressed-zero scale* or, colloquially, as a "suppressed scale." This kind of scale distinguishes frequency meters from the great majority of other electrical instruments, such as voltmeters, ammeters, etc., whose scales start at zero. The *complete* scale of this frequency meter is shown in Fig. 1. It is a quadrant or 90° scale exactly 3" long and covering only five cycles. Each cycle subtends an angle of 18° or a scale length of 3/5". The scale interval is 0.06" = 0.1 cycle.

A tachometer can be used as a frequency meter by applying the formula given above. If the Fig. 1 tachometer is connected to a two-pole machine, "3600" on its scale will correspond to 60 cycles, "3450" to 57.5 cycles and "3750" to 62.5 cycles, as the dotted lines indicate. This 300-r.p.m. or 5-cycle portion of the tachometer range subtends an angle of 27° (or 0.9 inch) instead of 90° (or 3 inch) as on the frequency meter. One cycle is 0.18" instead of 0.6".

The tachometer and the frequency meter sketched in Fig.

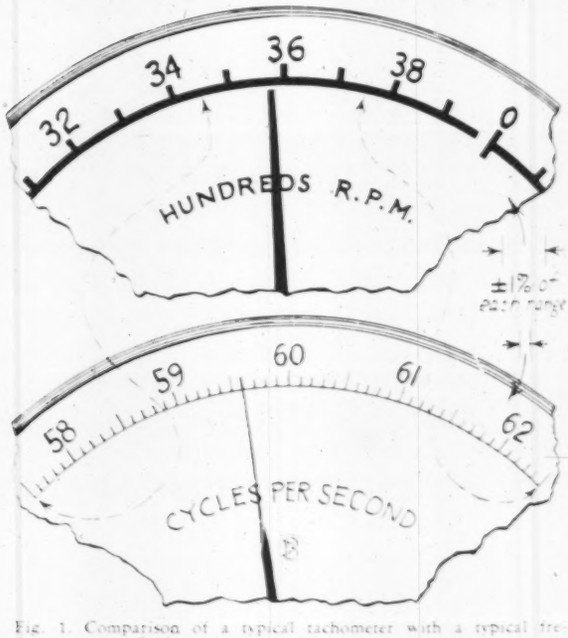

Fig. 1. Comparison of a typical tachometer with a typical frequency meter—both accurate to ± 1%.

	Tachometer	*Frequency Meter*
Scale length	12"	3"
Scale range	4000 r.p.m. = 66.6 cycles	5 cycles
Interval, 1 cycle	0.18"	0.6"
Readable to	0.5 cycle	0.02 cycle
= 1% =	1.33 cycle	0.1 cycle

*This section has been inserted in Mr. Spencer's text by M. F. Behar, who assumes responsibility for assertions and recommendations.

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But this national emergency has created a shortage of electrical instruments, so that even plants enjoying priority have to wait. The top shelves of stockrooms are being searched for old instruments. "Irreparable" instruments are being "repaired." And —perhaps most important—all instruments in use must be maintained in good condition . . . by the users. Hence the crying need for this serial—the first and only one of its kind.

NOTICE TO STUDENTS IN INDUSTRY

Chapter I (Direct-current Instruments) appeared in the August 1941 issue of *Instruments*, pages 226-240.

The first part of Chapter II (A-c. Ammeters and Voltmeters) appeared in the September issue, pages 255-268; the second part in the February issue, pages 48-57.

Chapter III (A-c. Wattmeters), December issue, pages 394-403.

Chapter IV (Summary of A-c. Types), December issue, page 404.

Chapter V (Instrument Transformers), December issue, pages 405-408.

Back copies of *Instruments* are available at 25 cents each as long as they last.

It is expected that this serial will be completed and brought out in book form before June.

1 are both "ordinary" or "typical." An ordinary tachometer with a range of 0 to 4000 r.p.m. cannot be read more precisely than to about 30 r.p.m. When such an instrument is applied to a two-pole machine (where 3600 r.p.m. represents 60 cycles per second) it cannot be read more precisely than to about half a cycle. An ordinary frequency meter can be easily read to a tenth of a cycle with a limit of uncertainty of a fiftieth of a cycle.

But that is not all. The guaranteed accuracy of an ordinary tachometer is seldom better than ± 1% of its scale range. For a 0-4000-r.p.m. tachometer the zone of uncertainty would be 80 r.p.m., corresponding (in the case of a two-pole alternator) to 1⅓ cycles per second. The guaranteed accuracy of a frequency meter, likewise, generally is ± 1% of its range. If it has a range of five cycles, the zone of uncertainty is 0.1 cycle.

These ± 1% zones of uncertainty are shown at the right of Fig. 1.

Some readers may think it "unfair" to represent the tachometer with a wide pointer and the frequency meter with a knife-edge pointer. If they examine Fig. 1 under a magnifying glass they will see that the width of the tip of the pointer of each instrument is exactly one-sixth of the ± 1% uncertainty zone of each instrument. Nothing could be fairer! Fig. 1 shows conclusively, therefore, that an ordinary frequency meter is an instrument of precision as compared to an ordinary tachometer. As a matter of fact, the highest precision attained in practical electrical measurement work (outside of laboratories) is in the determination of frequency: a precision of one part in 1200 is commonplace. In laboratory determinations of frequency, a precision of one part in a million is commonplace.

There are on the market more than fifty makes, and more than fifteen distinct types, of tachometers. A detailed analysis of their characteristics would take several pages. In brief, the *chronometric type* is recommended as the type which best combines precision, accuracy, convenience, reasonable cost and availability. It comprises a revolution counter, a high-grade timepiece and an automatic device for engaging and disengaging the registering mechanism at the beginning and end of definite time intervals—all within a dust-proof case. Its dial reads directly in r.p.m., so that no computation is necessary.

Where a shaft positively associated with the test frequency is rotating at constant speed, the test frequency may be determined by using a revolution counter and a stop watch. This method is well-known but the various factors affecting its precision are not so well-known.

First of all, since it is impossible to eliminate starting-and-stopping errors, the time interval during which the revolutions are counted should be sufficiently long. If the starting-and-stopping errors total half a second, a one-minute interval is too short because the uncertainty due to this cause alone is nearly 1% of the count.

The revolution counter should be a good one. Cheap ones are subject to errors—as can be proved by the fact that two or more cheap counters will not always agree in their registration increments after being driven positively and simultaneously for several minutes.

The counter should be used correctly, so that it will unquestionably register the exact count. The drive should be positive rather than frictional.

The stop watch should be a good one, in good condition. Not only should it be a good timepiece but its starting and stopping mechanism should work uniformly. The counting period depends on the precision of the watch: if the watch reads to fifths of a second, its total uncertainty is two-fifths of a second and it should be used to measure counting intervals longer than one minute.

Thus, it is apparent that a counting interval of at least two minutes is required for determination of frequency by the counter-and-stop-watch method when calibrating "ordinary" frequency meters. Some workers standardize on five minutes.

On the whole, the best comparison standard for calibrating a frequency meter is a precision frequency meter with a more open scale. If the instrument under test can be read to 0.1 cycle, the standard should be of 0.02-cycle precision and, preferably, 0.02-cycle accuracy.

In certain industries, such as power, communications, automotive, aircraft, etc., an electrical-instrument maintenance man who inquires about the facilities in his company's laboratories and testing departments may discover that "frequency meters" of superlative precision are available—though called by other names. He may discover that in an engine testing laboratory (for example) there is some apparatus such as the one shown in Fig. 1A, which embodies a timer which reads to 1/1000 minute and a revolution counter which reads to 1/5 revolution—the *accuracy* being guaranteed equal to this *precision*. When applied to a 3600-r.p.m. machine for a period of one minute, such an equipment is accurate to 0.105% (or to 0.063 cycle per second when checking a frequency meter at 60 cycles).

In an electrical laboratory he may discover a cycle counter and an electric stop-clock which can be spared for his use. This combination likewise constitutes a high-precision standard.

In various departments dealing with radio apparatus he is sure to find thermostated crystal oscillators, beat-fre-

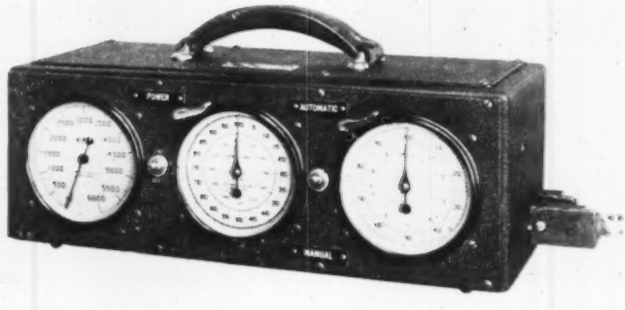
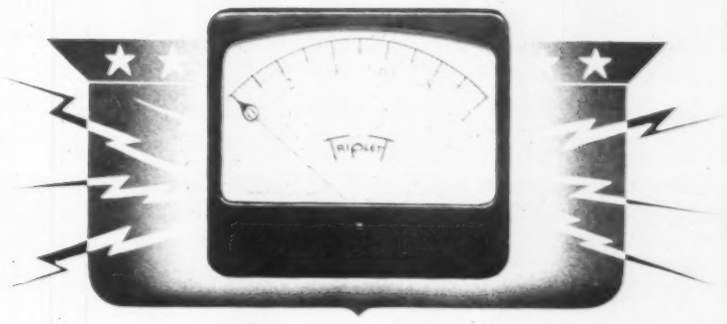


Fig. 1A. Certain instruments not known as frequency meters are utilizable as standards for calibrating frequency meters when the adjustable frequency is obtained from a variable-speed machine. Here, for example, is a "Chrono-Tachometer" manufactured by the Standard Electric Time Co. for engine-testing work. At the left is a tachometer (which is a convenience but is not used for precise determinations). The middle dial is a revolution counter with two hands (like a watch), the longer one reading to one-fifth of a revolution on the outer scale. The right-hand dial likewise has two hands, reading to minutes and to thousandths of minutes. An automatic stop permits integration of revolutions and time for continuous test runs or for exactly-timed intervals. The accuracy over a sufficiently long period is limited only by the accuracy of the time measurement. If the timer is driven synchronously with a system controlled from Naval Observatory signals, the maximum error for a one-hour run would be of the order of a thousandth of one percent.



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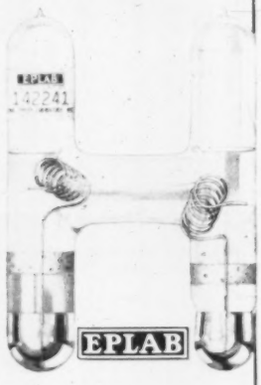

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quency apparatus, etc., which can be hooked up to provide a source of controllable low frequency; but before using such equipment he should make certain that the low-frequency alternating current therewith generated will have a wave-form closely approaching a sine curve; because some types of frequency meters (other than the mechanical type) are subject to wave-form errors and should not be calibrated on an excessively-distorted output.

[End of section written by M. F. Gmur]

VIBRATING-REED FREQUENCY METER

Vibrating-reed type frequency meters are made both in switchboard and portable forms, the portable form (Fig. 2) being the most widely used in test work. Fig. 3 shows the internal construction of a typical vibrating-reed frequency meter. The mechanism consists of spring steel reeds *R*, attached to the bridge-piece *B*, this assembly being called the reed-comb. The armature *A*, of the electromagnet *M*, is also mounted on the bridge-piece. The cross pieces *C* (one at each end of *B*) on which the bridge is mounted, are made

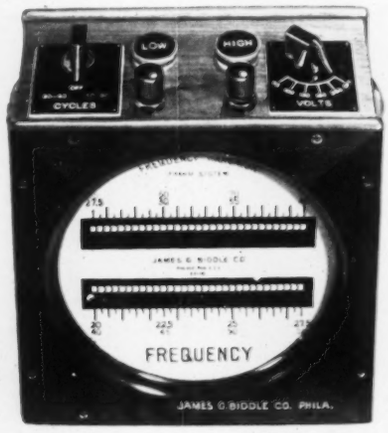

Fig. 2 Portable type "Frahm" frequency meter, having two rows of reeds and range-doubling device; and with selector switch for operation on all voltages between 50 and 300. *Figs. 2 to 5 inclusive, courtesy James G. Biddle Co.)*

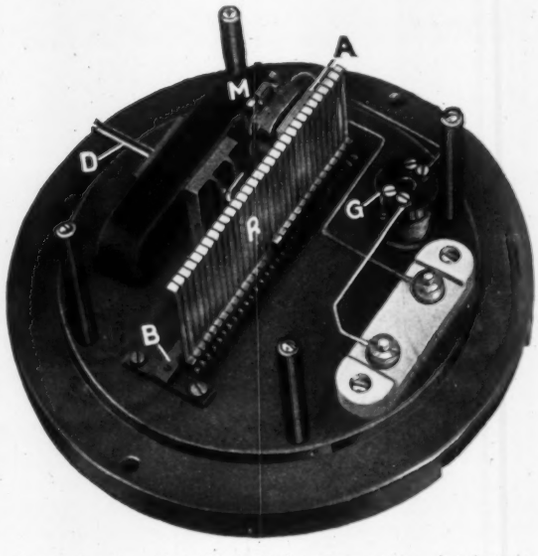

Fig. 3. Interior of a "Frahm" frequency meter, showing—in principle—the construction and operation.

A—Armature of electromagnet *M*.
B—Bridge-piece on which are mounted the reeds *R* and armature *A*.
D—Amplitude adjusting screw by which the air-gap between *A* and *M* is set.
G—Protective series resistance for *M*.
M—Electromagnet.
R—Tuned reeds, each one of which is adjusted to respond by resonance to a given mechanical vibration set up in *B* through *A* by the alternating current in *M*.

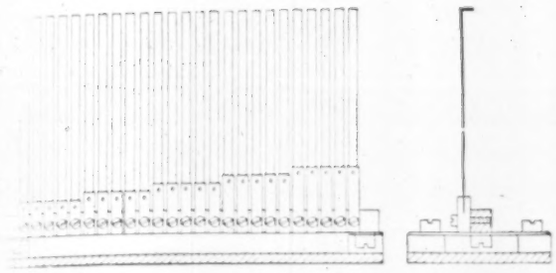

Fig. 4. A set of steel reeds as used in "Frahm" frequency meters.

of flexible steel to allow the armature and reed-comb to be vibrated by the electromagnet when the electromagnet is energized by the alternating current whose frequency is to be measured. The series resistor G is shown with its series connection in the circuit and the screw rod D is for controlling the gap between the electromagnet M and armature A, which in turn controls the amplitude of vibration of the particular reed or reeds which indicate the frequency being measured.

The fundamental principle on which the vibrating-reed frequency meter works is that when an elastic body is subjected to rhythmic impulses of the same frequency as the natural period of vibration of the body itself, it is caused to vibrate by reason of "sympathetic vibration" or resonance. As plainly shown in Fig. 4, the reeds are of different lengths or weights and they all have different periods of vibration (as calibrated). Thus the reed with the same period as the frequency of the armature will vibrate.

The vibrating-reed frequency meter is connected in a circuit similar to a voltmeter, but care must be taken to have the proper amount of resistance in series to prevent the coils from burning out or the reeds from oscillating with too great an amplitude causing them to bend or break.

This type of frequency meter is widely used in repair and maintenance work. Greater benefits could be derived

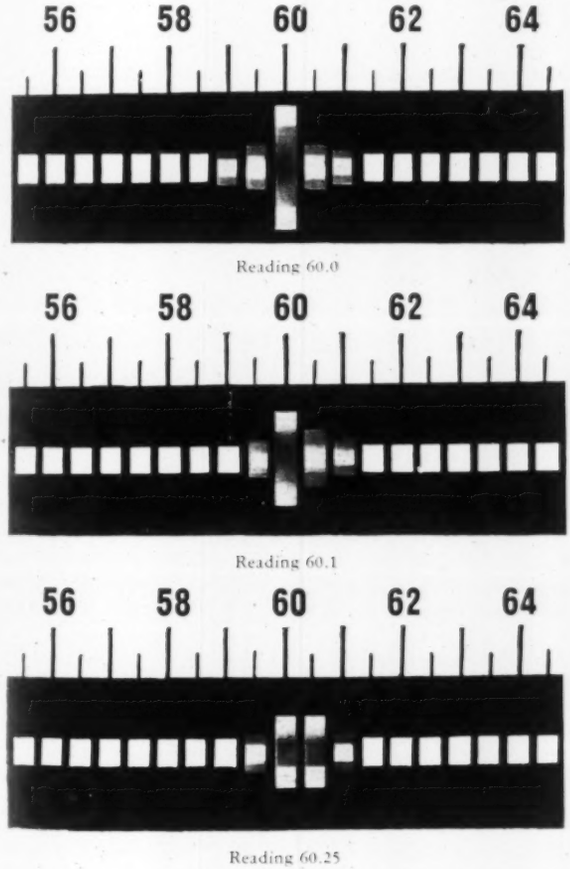

Fig. 5. Facsimile scales showing how to read a "Frahm" frequency meter.

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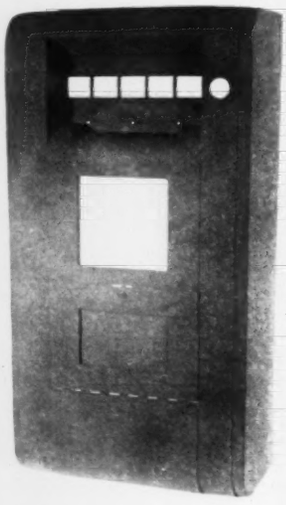

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by the users through better understanding of the proper method of reading the scale. Hence the following illustrated explanation of the proper method of reading frequency indications.

The three views shown in Fig. 5 should dispel the erroneous idea which many users have, that the vibrating reed frequency meter has only a definite number of possible indications equal to the number of reeds. It can be seen from the three views that intermediate points may be read. Vibration begins at about 2% below the exact value to which the reed is tuned, reaches its maximum at the exact value, and extends to about 2% above that value. Therefore, more than one reed usually is in motion, and from the respective lengths of the bands formed by the white-enamel reed tips across the scale-opening, the value of the frequency may be estimated to one-fourth of the interval between successive reeds. Reference to the three scale-images in Fig. 5 will make this feature quite clear. On the upper scale the reading is evidently 60. On the lower scale, the reeds indicating 60 and 60.5 are vibrating equally, so that the reading is half-way between these two values, that is, 60.25.

On the middle scale, the reed indicating 60 is vibrating more than any other, which means that the reading is nearer to 60 than to any other scale division. Since the reed indicating 60.5 is in next greatest vibration, the reading is above 60 rather than below, but is less than 60.25. Comparing the relative amplitude of the 60 and 60.5 reeds, one can safely estimate in this case that the reading is about 60¼ or approximately 60.1.

Maintenance

Of interest to maintenance men is the fact that there are no moving parts except the steel reeds. Therefore there are no troubles due to friction from pivots and jewels. Also, there are no springs necessary for conducting current to and from moving coils. The instruments are inherently rugged and are unaffected by mechanical shock. Voltage variations, ordinary temperature changes, effects of stray fields, or the position of the instrument (either horizontal or vertical) have little or no effect on accuracy. As with all types of assembled devices, however, there are possible causes of errors, herewith given to enable the repair man to analyze troubles.

(1) Distortion or bending of reeds, due to excessive oscillatory motion, may change the calibration of the reeds—hence calibration errors. This may be caused by too high a voltage or by incorrect adjustment of the amplitude-adjusting device, so that chattering occurs, when the reeds are either fatigued or strike for too long a time on the damping bar, which may cause chipping of the enamel on the reed. In more recent instruments, the damping bar is set behind the bent-over portion of the reed so that the reed strikes on its flat surface and is less likely to be injured. Recalibrating individual reeds requires facilities for varying the test-line frequency and holding it constant within 0.02 cycle. It calls for high skill, special experience and knowledge of vibration engineering principles. This book's purpose being to tell how to service instruments without returning them to the manufacturer, we shall outline the procedure, but in a brief style understood only by experienced workers:

Not only period, but relative amplitude with reference to neighboring reeds, must be altered in small steps. Both are functions of ratios of moments of inertia to restoring force. Mass of free end, and stiffness of portion nearest clamped end, are important. When applying a drop of solder in corner, do not alter elastic properties of steel. Before grinding down a tip to reduce its mass, look for solder, lacquer, etc., the scraping of which might obviate all need of grinding, then observe effects of small frequency variations.

(2) The thumb nut for adjusting the electromagnet air gap is made fast to the screw rod by a set screw just inside the case. If this screw should loosen and become dislodged, the air gap adjustor would be ineffective.

(3) Since this instrument has electromagnet coils and series resistors there is always the possibility of shorts and open circuits. A shorted resistor would mean a larger part of the circuit voltage across the electromagnet coils, producing excessive vibration of the reeds. This condition, if

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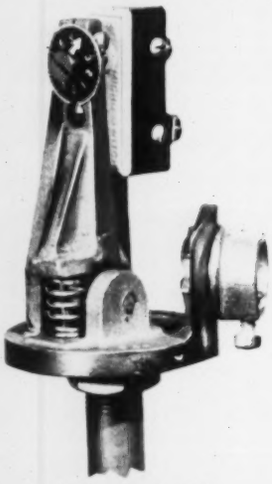

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not corrected immediately, may cause coils to burn out and possibly bend or fatigue reeds. Partly shorted electromagnet coils may be noted by a reduction in the amplitude of reed movement, while totally shorted coils result in no reed action and therefore no indication. If the circuit is found to be open, check all connections (both solder and mechanical) to be sure they are not loose. Next check the series resistors and the electromagnet coils with an ohmmeter, or with the instrument connected to the circuit use a voltmeter or a low-resistance lamp to check by shorting each resistor spool and the electromagnet coils one at a time. If these checks fail to bring the fault to light on double frequency range meters, check for defective contacts on the range-changing switch.

If, during repairs, both reed-combs are removed, they should be marked to insure correct replacement.

Dismantling and reassembling for the purpose of repairing or replacing parts are simple operations. A careful inspection of the construction of this instrument should be sufficient for one experienced in the repair and maintenance of electrical instruments. Let us, however, follow through step by step the operations necessary to replace an electromagnet coil or reed, the two parts most likely to become affected if the instrument is misused. As regards the replacement of a reed, a small six-inch screwdriver would be the only tool required to make the change. A soldering iron in addition to the screwdriver would be the only tool necessary in the replacement of an electromagnet coil. Series resistors, if defective, are so accessible that replacements can also be made using only these two tools. Most of the parts for these instruments are interchangeable and may be ordered from the manufacturer by giving a careful description of the type and range of the instrument as well as the particular part required.

The interior mechanism is rendered accessible by the removal of the cover and dial. To replace a coil, the lead connections are unsoldered and the pole-piece on which the coil is mounted is disassembled from the electromagnet core by the removal of the two screws holding the pole-piece to the magnet. In replacing the coil, the reverse procedure is followed.

The reed-comb may be dismounted after the cover and dial have been taken off, by removing the four screws that hold the semi-flexible end pieces (see Figs. 3 and 4) to the sub-base of the instrument. With the bridge assembly removed from the instrument, the reeds may be detached by the removal of the single screw that holds each to the bridge. Reassembly of the reeds to the bridge, and the bridge to the sub-base, should be made by the reverse of the dismantling operations just outlined.

Care should be exercised when connecting to a circuit, to be sure that the voltage is not too high for the capacity of the instrument. If desired to be used on high voltage, use with a step-down voltage transformer or with sufficient series resistance to lower the voltage to the normal rating of the frequency meter.

(To be continued)

Wire Resistance Strain Gages

(Continued from page 114)

ment with two, four and six channels is also readily available to 1000 c.p.s., as are regular General Electric and Westinghouse models. In any moving-mirror oscillograph the lower the frequency for which they are designed, the larger may be the mirror, and the greater the sensitivity. High frequency is seldom of importance in aircraft testing. Together with such devices, switching of different groups of gages is becoming customary. These moving-mirror oscillographs are the most portable, and sufficient for all airplane vibration, landing stress, and ordnance recoil problems.

Finally, cathode-ray oscillographs are ideal for laboratory use. For continuous vibration, measurements may be made without photography, and where required, the pattern

be recorded with an ordinary camera. For high-speed ... in the study of transient stress waves, cathode-ray ...s with 5000 to 6000 volts on the plates are available, ... film speeds on a drum camera up to 800" per second ... obtainable. Traveling waves in steel bars, Fig. 5, and ...sses in shot-gun barrel, Fig. 6, were taken with a three-...ment oscillograph of this type.

While wire strain gages are in themselves extremely ...ple, their best use for a given purpose requires a thor-...gh knowledge of electrical measuring instruments and ...ethods. In some cases amplifiers (roughly described as ...igh-fidelity" in radio parlance) are suitable. In other ...ses far more exacting standards are required. It must ...lways be borne in mind that in general amplifiers of flat

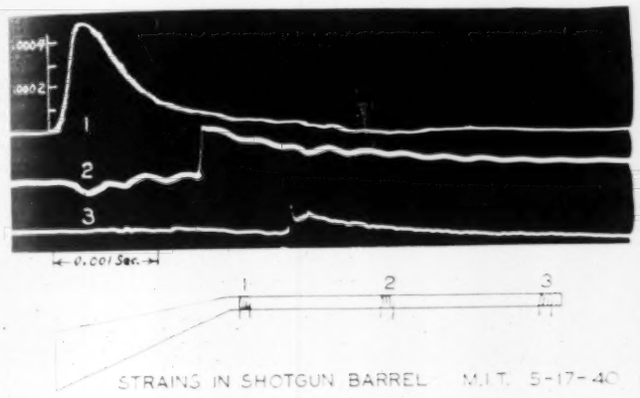

Fig. 6

response over wide frequency ranges, stability and great amplification are not manufactured except for special purposes, and are, therefore, expensive in both time and money. Wherever the measurements to be made are sufficient for their engineering purpose at ± 5% accuracy, there is a great waste involved in providing equipment capable of measuring to ± 1%. The same discrimination must be used in measuring strains in aircraft structures under static loads; it is an unfruitful procedure to measure strains to ± 1% on sections from which are calculated load in members which vary in gage by ± 5%. On the other hand, where the determination of forces is important as for instance in weighing reactions of models in a wind tunnel, it may be desirable to work to ± 0.1%.

Wire gages are a recent invention; both they and the necessary equipment for their use are being rapidly developed and it may reasonably be expected that this fundamentally simple system will be of great service in all fields of engineering and industry.

TWA Instrument Department

(Continued from page 102)

possible with the stop watch method against a variable-drive mechanism. This stand consists of an 1800-r.p.m. synchronous motor driving through a 3600-to-1 compound worm reduction gear assembly to a turn table head on which is mounted the Turn and Bank Indicator. This head also carries the vacuum manometer vacuum regulator relief valve and transfer valve allowing a constant vacuum source throughout a 360 degree turn.

The calibration procedure, therefore, consists only of installing the instrument and regulating to the required vacuum. It then is only necessary to operate the motor control in both right- and left-hand turns. The rated turn being held constant by the synchronous motor will, therefore, give an accurate indication of the calibration of the instrument being tested.

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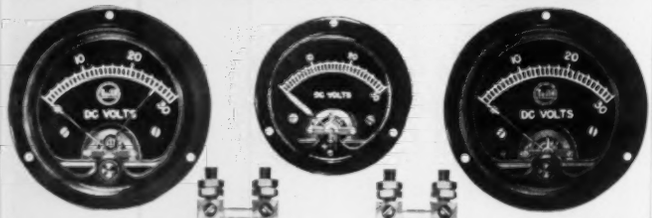

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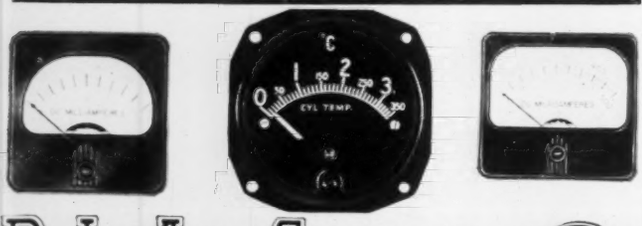

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This stand allows temperature compensation of all instruments throughout their operating range in addition to extremely accurate indication of calibration of altimeters for both planes and ground station equipment.

(3) A stroboscopic tachometer calibrating stand, consisting of a synchronous motor driving through a variable reduction gear box to a manifold drive on which six tachometers can be calibrated at one time. In connection with this drive there is attached a stroboscopic device which gives indications at each 50-r.p.m. to an accuracy of 0.005%. Operating in conjunction with the stroboscope is a master tachometer which is held to an accuracy of ±5 r.p.m. through the entire scale. The master indicates the r.p.m. desired and the stroboscope gives actual accuracy at that r.p.m. A larger volume of instruments can be calibrated at one time and owing to the fact they are held constant with a synchronous motor and through the use of the 60-cycle line frequency stroboscopic action of this light, a much higher degree of accuracy can be maintained.

Anyone at all familiar with TWA practices knows that the company has led in experimental work in many fields. No expense has been spared in seeking instruments or methods contributing to safety and dependability of flight. In addition to the three testing equipments described above, a carburetor ice warning unit, a synchroscope to insure synchronous engine operation on multi-engine ships, and de-icer accessories, are a few of the devices worked out in our development section.

Intensive Course for Aircraft Instrument Mechanics

(Continued from page 101)

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Army's Flying Laboratory

(Front-cover Photograph)

Lieut-Col. Thomas L. Thurlow of the U.S. Army Air Forces is shown taking a drift meter reading in an Army flying laboratory. This drift meter is gyro-stabilized to eliminate the effect of the airplane's "roll," so readings can be taken three or four times faster than with an unstabilized drift meter.

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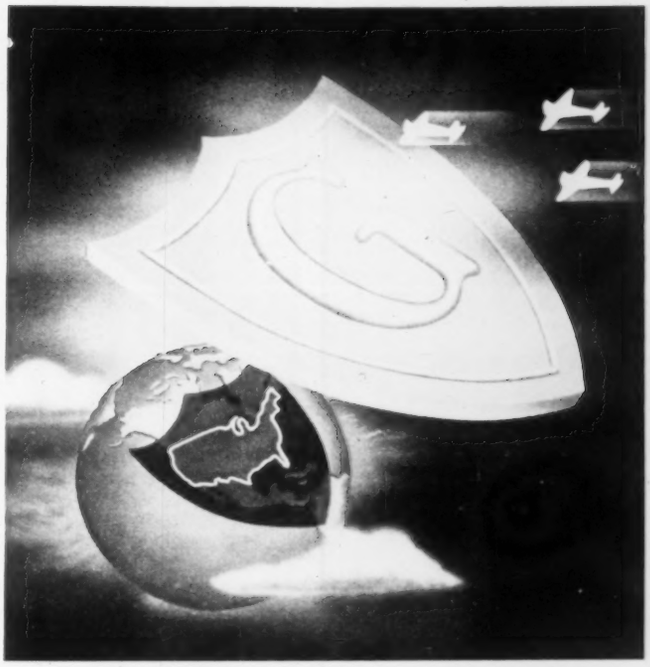

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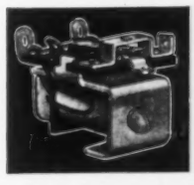
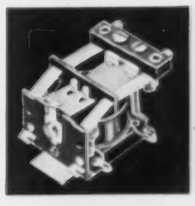
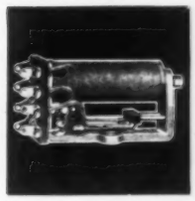


SERIES 195 RELAY (left) Contact capacity 100 watts. Switch capacity double pole, double throw. Maximum coil resistance 2,000 Ohms. Vibration resistant. Specified where weight and size are of utmost importance, as in aircraft. Weight, ¾ oz. Size 15/16" Dia. x 1¼" L. Available DC only.

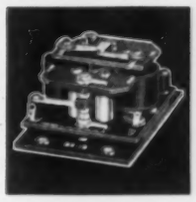
SERIES 165-24V. VIBRATION RESISTANT RELAY (right). Contact combinations up to double pole, double throw, with contact capacity up to 12.5 amp. per pole, non-inductive AC. Overall dimensions 2½ x 1 9/16 x 1⅝". Weight: (DPST contacts) 5 oz. Available DC only.





BK-10 RELAY (left) Precisely counter-balanced to resist extreme vibrations. Built to rigid U. S. Signal Corps specifications.

BK-16 RELAY (right) Built to minimum tolerances. A production line product. Furnished to custom-built specifications. Another U. S. Signal Corps Relay by Guardian.



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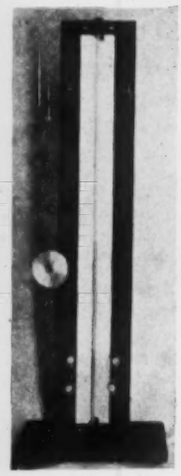

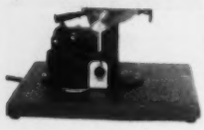

OSCILLATING TABLE

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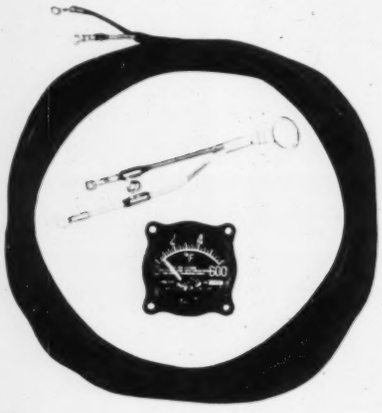

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Measuring the Elastic Airplane

(Continued from page 97)

plates and landing gear struts. With these gages the strains in any component of the airplane can be measured and recorded, whether they are steady (as the wing spar stresses during the pullout from a dive) or occur in a small fraction of a second.

This information is of great value to the vibrations and flutter engineer who must assure the safety of the airplane's wings, tail surfaces, flaps, antenna mast, etc., under high-speed conditions.

Thus the problem of evaluating factors affecting the dynamic structure of the airplane is now being carried to the point where it is practical to measure simultaneously not only the local accelerations and vibrations affecting the structure due to them. The former information gives the designer the magnitude of the loads that are being encountered, and the latter tells him just where and how great are the stresses being built up in the structure to react against these applied loads. Both can be recorded on a single chart, and their correlation is most interesting and important. For it is the correlation of applied load and

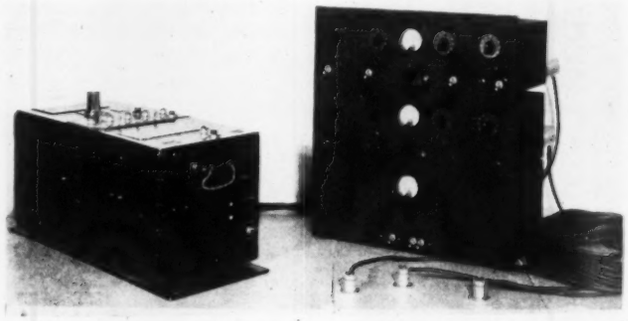
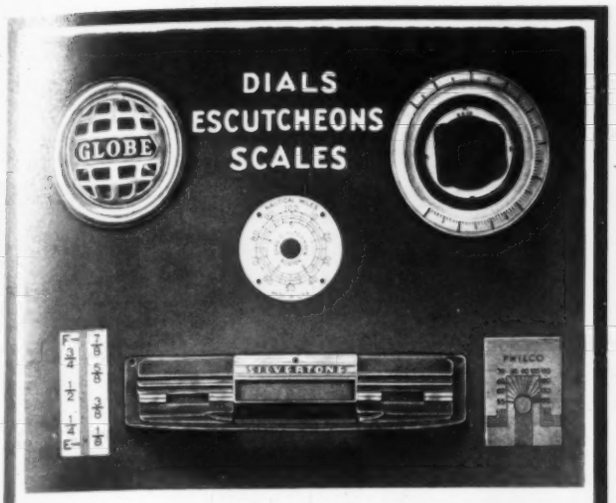


Fig. 5. Martin flight test vibration equipment including eight amplifier channels, power supply, oscillator and oscillograph.

reacting stress that proves the airplane a quite deformable structure: an elastic body easing its load in one part while increasing its load in another, always maintaining complete equilibrium of total forces. It is the interchange of energy, non-existent if the airplane is considered a rigid body, which is real in the actual airplane, and in numerous cases has resulted in serious consequences to the aircraft.

Studies are being made constantly, and information being compiled relating to these dynamic phenomena. The instrumentation can be greatly extended along the lines mentioned, and this is being done, so that a remarkable amount of data can be obtained during a single flight test. The electrical circuits which have been evolved after years of often disappointing results are in answer to the problems of interference encountered in flight testing due to radio, engines, generators and mechanical shock. The pickups are the result of hundreds of tests under the most trying conditions of temperature, electrical variation, shock, shielding and handling. The technique has been developed even in small details, as for instance the method of attaching a pickup by a suction cup for a routine ground vibration test, shown in Fig. 2. The apparatus and the technique now constitute a practical tool for the ready use by the research as well as the production engineer, and every day new uses for it are being reported. They point the way toward more efficient design in widely-separated fields from sub-zero fatigue measurements on materials, to the study of dynamic characteristics of hydraulic bleeder valves.



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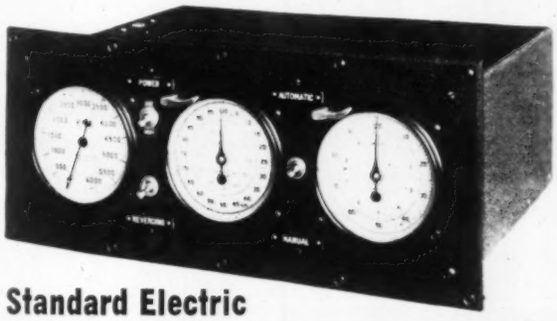

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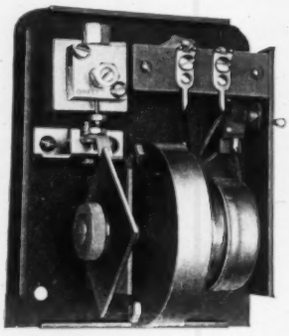
When writing to manufacturers directly, please mention this department as your source of information. Or write to Information Section, Instruments Publishing Company.

Repeating Cycle Timer

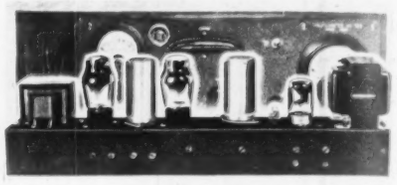
For periodic purging of condensate from certain types of curing or molding equipment (also beneficial in creating adequate heat distribution), new "Repeating Cycle



Timer" has been developed. This new unit, also known as the "Blow-Down Timer," is used in conjunction with a diaphragm-motor reverse-acting condensate valve, and with suitable temperature or pressure control on the application, permits the admission of fresh steam without affecting an appreciable pressure change within the apparatus. This new instrument allows user to control duration as well as period of blow-down cycle.—*Taylor Instrument Companies, Rochester, N. Y.*

"Profilometer" Power Pack

For use with "Profilometers" (*Instruments*, July 1939, page 173) new "Power Pack" accessory unit has been designed to make possible the use of Profilometers on



a-c. lines. Until recently, Profilometers have been self-contained with batteries which permitted full portability. For their uninterrupted use in one location, particularly on three-shift inspection operations, Power Pack permits power to be supplied from a 115-volt 50-60 cycle a-c. source. Existing Profilometers having serial numbers of 75 or greater can be converted for a-c. operation, being returned to manufacturer. Power Pack can also be specified as a part of a new instrument.—*Physicists Research Co., 343 South Main St., Ann Arbor, Mich.*

Fusion-method Thermometric Sticks

Makers of "Tempil" Thermometric Pellets" announce a new form of their product, called "Tempilstik®." Like "Tempil®" pellets, each "Tempilstik®" has a specified melting point. Thus a "300 Tempilstik®" drawn across a surface heated to less than 300°F., will leave a chalklike mark and this mark will melt sharply into a liquid streak when the surface reaches 300°F. New sticks are available from 125°F. to 1600°F., in "convenient" temperature intervals, and have a mean accuracy of within 1% of the temperature stamped on each stick. They constitute a means of leaving a temperature signal mark on less-accessible places, such as vertical, inclined and overhead surfaces. Properly used, each stick will yield up to 1000 temperature determinations, it is said. Among recommended uses: signalling desired preheating temperatures in the welding of steel, special alloys, cast iron and non-ferrous metals; in local heating, heat-treatment and fabrication of metals generally; particularly useful in black-heat range. "Tempilstiks®" come packed in individual tube that fits pocket and prevents breakage. —*The Tempil Corp., 132 W. 22nd St., New York City.*

Electric Predetermined Count Controliers

Any number from 1 to 9999 can be quickly set up on new "Monitor Model PDC-E Predetermined Electric Counter," by simply turning knob pointers to the proper digits. When the count reaches the pre-

determined number thus set up, a control and signal circuit is closed (or opened). This circuit may be used to sound an alarm or operate a relay to perform any desired function. Counting ceases at the predetermined number until a reset lever is depressed (which requires less than half a second), making the instrument ready for a new count cycle. To change the predetermined number, the knob pointers are merely turned to the proper digits before resetting. New counters are particularly useful in counting objects passing on a conveyor or delivered from a machine. Being electrically actuated, counters may be located at a distance from the things being counted, are actuated by any switch, relay or photo-electric unit with a closed period of 0.035 second or more and an open period of 0.040 second or more.—*Production Instrument Co., 702 W. Jackson Blvd., Chicago, Ill.*

ible Recording System Interchangeable Units

Oscilagraf System" was originally for meeting unusual requirements sure recorders. A high degree of

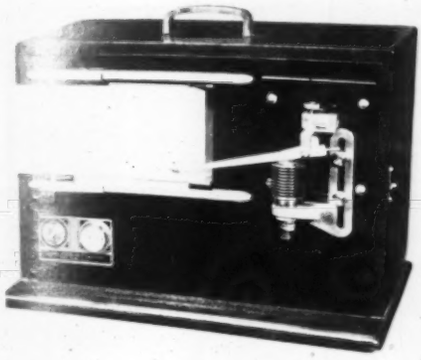


Fig. 1

unitization allows furnishing custom-built multi-purpose recorders with minimum delay. Fig. 1 shows a standard pressure recorder quickly made up from stock elements; Fig. 2 shows a kymograph which is "special" in its application (gynaecology) but "standard" as an instrument. System is unitized into three principal sections: (1) paper-handling mechanism, (2) paper-drive mechanism; motors, controls, etc., (3) measuring-and-recording element. Drive Mechanism is instantly adjustable to any width of roll paper up to 3½". Maximum roll diameter is 4" and core hole must be ⅝" or over. Where use does not justify expense of specially printed paper, unruled paper can be used. For many applications ordinary adding-machine paper is surprisingly satisfactory. Writing is accomplished at position where paper leaves roll in fixed registry. Thus, edge of paper can be used as a rigorous reference for measurement. Interchangeable motor plates are readily removed. In many applications, where move-

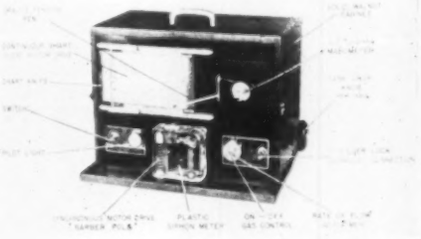


Fig. 2

ment of paper does not have to constitute a time axis, drive roller can be fitted with a pulley or coupling for attachment to a related device, thereby making the instrument a "co-ordinatograph" or "*X-Y* recorder." Responsive and writing section is so designed that measuring elements can be interchanged. Method of mounting on an integral plate allows interchange of complete elements. Each plate and accessories include adjustments for: (1) element to pen lever ratio—range adjustment; (2) adjustment to accommodate many sizes of measuring elements; (3) sensitive adjustment for pen zero. Complete recording apparatus is mounted on a panel and does not require the case to serve otherwise than as mounting and enclosure. Recorders can be mounted in any plane and with the paper issuing in any direction. Usual recorder is mounted on a panel 9" × 13" and requires 4" in back of panel. Panel can be extended to allow incorporation in an existing enclosure, or with other apparatus. With a measuring element mounted completely exposed on front of main panel, required projection space is 1⅝".—*Grafax Instrument Co., 872 Broadway, New York City.*

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*Where moving parts are not readily accessible, as in turbines, centrifugal pumps and other totally enclosed machines, and also for measuring vibrations per minute, we recommend our Frahm Vibrating-Reed Tachometers. Ask for Bulletin 1590-I.

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1211-13 ARCH STREET *Electrical and Scientific Instruments* PHILADELPHIA, PA.

Flight Recorder

Tests have just been completed (April 1942) and production begun, on perfected models of "Redhed Flight Recorder," an instrument weighing 20 lbs. and producing as

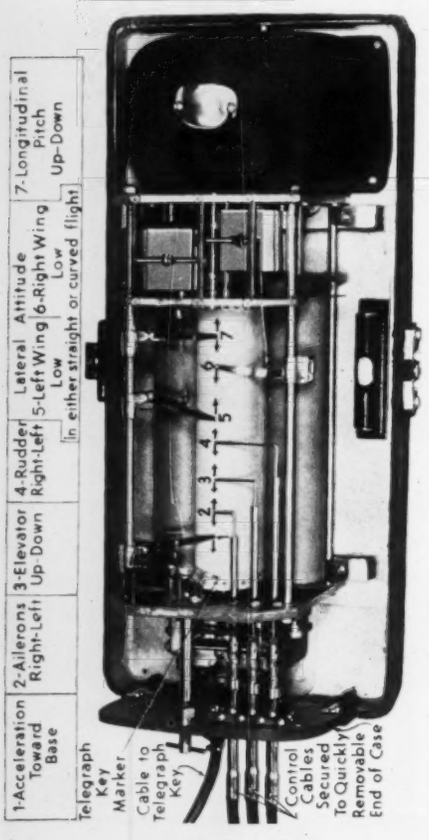

Fig. 1

many as seven permanent records on wax-coated paper charts (no ink). Fig. 1 shows one model designed for recording movements of controls and data on certain accelerations and attitudes, as explained in the legend at the left. However, manufacturer emphasizes ease of changing recording units; for example, instead of the longitudinal pitch unit (No. 7) an air-speed recording unit may be substituted. Number of possible combinations is enormous. Fig. 1 is largely self-explanatory but does not show the following features: (1) Springs to keep slack out of cables running to controls. (2) A remote control for starting and stopping the chart. (3) A red light which flashes each second while the chart is moving, and mounted with telegraph key on a portable clip board. Telegraph key or push button is used for marking in code any desirable information on chart. Accelerometers may have a spring of practically any scale desired. When recording only positive acceleration (Model A-2) the recording begins with +1.00 *G*. The maximum record (No. 1) is 1.00" long and, depending upon scale of spring used, may indicate almost any maximum load from +1.50 *G* (frequency 7 per sec.) to +21.00 *G* (frequency 44 per sec.). If a record of negative acceleration is required (Model A-3) total length of record may be 1.4". Record produced is ten times movement of accelerometer weight. In Model A-2 this ratio may be 5 to 1 if 30% lower frequency is advantageous. The chart (7" wide and 71 ft. long) may be driven by a spring motor in accelerations of less than 4 *G*. In higher accelerations a synchronous motor driven by a battery through a converter is used. Chart speed of 6" per min. (0.1" per sec.) is standard and is maximum for balance-wheel type spring motor. (Much faster speeds with governor type spring motor; somewhat faster speeds with synchronous motor.)—*The Impact Register Co., Champaign, Ill.*

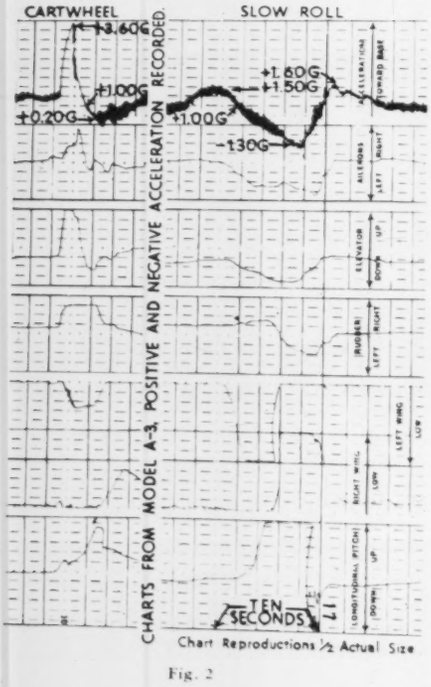

Fig. 2

Speed - - -

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Indicating Speed and Total Run.
Flexible Shaft, Belt, or Electric
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Decade Inductances

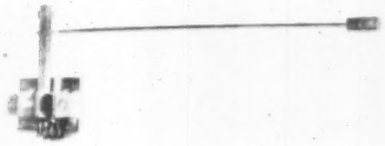
New type of Decade Inductance is announced as "in every respect a precision laboratory unit most valuable to the technician as a dependable aid in setting up experimental filters, equalizers, tuned amplifiers, phasing networks, etc." Announcement points out that although decade resistors and decade capacitors in all types of ranges have been available for a good many years, there has not been a precision decade inductance. New decade inductances are available in decades from 0.001 henries per step to 1000 henries. They have a Q of approximately 25 with a useful range of 50 to 20,000 cycles per second. Accuracy is ±5%, with an operating level up to 30db. In the higher ranges from 10 henries to 1000, the units are not recommended for operation over 1000cps. These instruments may be had in either two or three decades in any of the inductance ranges desired.—*New York Transformer Co., 51 West 3rd St., New York City.*

Cartridge for Seismographic Method of Prospecting

New "Spiralok" cartridge for seismograph dynamite provides a strong, rigid column, obviates need of stringing, lathing, taping and pegging commonly used in loading a hole, consists of dynamite packed in a strong paper shell equipped with a spiral thread. This shell screws into a stout spiral-grooved sleeve. Each cartridge is packed in its own sleeve of the same length. In loading, a sleeve is screwed over the two halves of adjacent cartridges until they butt together. A series of these cartridges thus joined provides a complete seismograph shot charge in a rigid column. Often a full charge can be loaded with one round trip of a loading rig, under conditions where two to four trips might be necessary otherwise. The column may be primed anywhere along its length.—*Explosives Dept., Hercules Powder Co., Wilmington, Del.*

Strain Gage for Parts Subject to Sudden Loads

A new type of electromagnetic gage to measure strain on machine parts subject to sudden loads is for application to punch presses, shears, press brakes, etc., where



strain rises abruptly to maximum and then falls sharply to zero. Gage serves as a protective device to forestall breakage of machine. It can be connected so as to give more than one kind of indication. A direct value of maximum strain can be obtained from an instrument in front of operator. A light or bell can be attached to signal when a predetermined strain has been reached. Gage need not be applied directly to vital part of machine under strain but to any part whose stress represents equivalent stress on the vital part. Comprising a rod, lever arm and head, the gage when attached to the machine looks like a side view of an automobile jack: handle is gage rod, jack is lever arm, base is gage head. Rod is fastened at either end to the machine in the direction of the strain. Lever arm, attached at its outer end to the machine, is at right angles to the rod. Gage head is mounted on a plate also attached to machine at a point on a line with lever arm. Gage head consists of an armature operating within two coils. Before the job is started, position of armature within coils is adjusted so that zero is registered on instrument. When machine is put into operation and strain exerted, the instrument, previously calibrated against known strain loads, then indicates to the machine operator the extent of the unknown strain.—*General Electric Co., Schenectady, N. Y.*

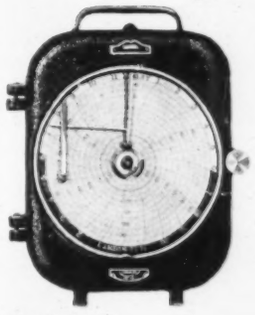
Service Men's Tester

"Model 030 Philco Dynamic Tester" is announced as "a sensational new piece of radio test equipment . . . amazing Philco development . . . locates trouble quickly and accurately in any kind of a radio circuit, utilizes an extremely simple process never before used in any other kind of test equipment and is simple and easy to operate." Of interest to *Instruments* readers is statement that "there are no confusing meters or indicating devices of any kind."

Tester weighs 5¾ lbs.; measures 8¼" × 5¼" × 3". To operate it, serviceman need only plug in on a-c. source; ground wire is clipped to chassis; a touch of the test prod indicates where a signal should be present. When a normal signal is not received at some particular amplifier stage, test prod is touched to adjacent parts of circuit and trouble spot thereby located. Tester amplifies and reproduces through its own loud speaker any kind of signal from any part of the circuit; traces the course of a signal through the radio and shows where signal is obstructed; indicates gain in any stage of any amplifier tube, checks tracking of r-f. tuning with respect to dial calibration; tests phase inverter stage for equality of audio input to push-pull output tubes; locates hum in condenser-resistor filter circuits, locates open screen grid and ave. bypass condensers; locates defective parts which cause noisy operation; tests phonograph pick-ups, crystal microphones or any device which generates a signal or noise of any kind.—*Philco Corp., Tioga & C Sts., Philadelphia, Pa.*

WEKSLER

At Your Service!

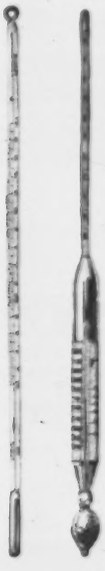


Left:
Portable Recorder
6 inch Chart
24 hour Clock

Right:
Dial Thermometer
In 3½, 4, 4½, 5 and
6 inch Dial Sizes

Catalog 115
Type 103
Bronze Case,
Glass Front,
Industrial

Catalog 115
Laboratory
Thermometers
and
Hydrometers



RECORDING THERMOMETERS
Furnished with 6", 10" or 12" Charts

For information on
Dial and Recording Thermometers, send
for Catalog 300 DR
For others, send for Catalog No. 115.

Weksler Thermometer Corporation
52-56 WEST HOUSTON STREET, NEW YORK, N. Y.

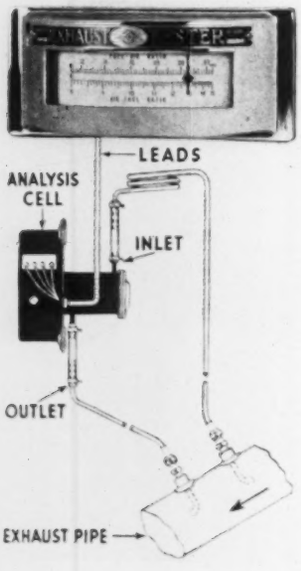
WE MANUFACTURE:

- Tubular Rheostats with Lubricated Slide Contacts.
- Four-Range Rheostats.
- Rotary Drive Rheostats for Switchboard Mounting.
- Table Rotary Drive Rheostats.
- Vertically Mounted Table Rheostats.
- Adjustable Resistors.

PROMPT DELIVERY

Exhaust Gas Tester for Engine Test Stands

Special Exhaust Gas Tester, designed and built for test-stand use in the aviation and in automotive industries, provides a ready means for making distribution tests and for quickly and accurately determining efficiency with which fuel is being burned in any



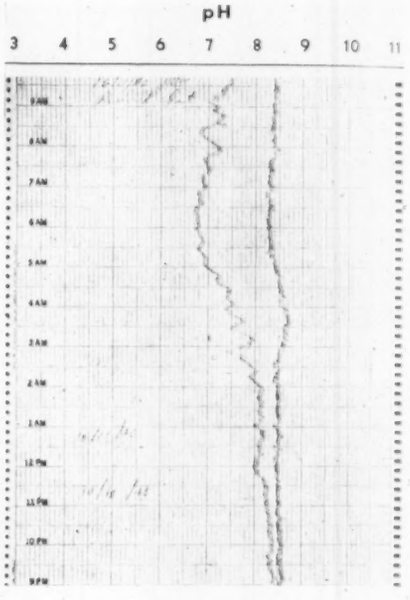
or all cylinders of an engine under test. All types of internal combustion engines may be tested with it. Results are shown on an indicator having a double scale 4½" long, reading in fuel-air and air-fuel ratios. In addition to indicator, new testing equipment includes an "aero type" analysis cell and all lead wires for connecting these two units, in addition to standard installation parts such as sampling nipples, hose connectors and copper tubing. Instrument employs thermal conductivity principle of gas analysis. Exhaust gas samples from the engine are conducted through tubing to the analysis cell, where their thermal conductivity is measured to determine completeness of combustion in engine. Maximum speed of response is attained by locating the cell close to engine, thus reducing distance which the sample must travel. Indicator, however, being connected to the Analysis Cell electrically only, may be mounted on a panel-board remote from engine. Indicator is designed for panel mounting; its zero adjustment is on front. For distribution tests, a large engine manufacturer's installation arrangement (used principally for testing twin-row 14 cylinder engines) is as follows: Each cylinder of engine under test has an exhaust pipe which runs to a common exhaust stack, about 4 ft. long, extending directly to rear. A sampling nipple is placed in each exhaust pipe, about midway to the stack. (If sampling nipple were located close to outlet, pulsations could suck-in outside air and thus dilute its sample of gas.) From each nipple a length of $^3/_8$" copper tubing passes through wall separating Engine-stand Room from Instrument Room. These tubes extend to a panel-board where they protrude about 1" through individual holes. Protruding ends of tubes not in use are closed with wooden plugs. On face of board, directly under each tube, is marked the number of the connected cylinder. A rubber hose to inlet of analysis cell permits testing in quick succession all 14 cylinders. This engine manufacturer utilizes also a suction on outlet of analysis cell. Although suction is probably unnecessary to insure good flow of gas, analysis cell outlet should be provided with a section of metal or rubber tubing not less than 3 feet long to insure that no room air is drawn back into cell. Moreover, downward slope of any part of a sampling line, from cylinder to analysis cell outlet, should be ample to insure good drainage of condensate.—*Cambridge Instrument Co., Grand Central Terminal, New York City.*

Dynamotor Contactor

New contactor specially designed to start and stop dynamotors used with aircraft equipment is available for either 12- or 24-volt d-c. circuits, conforms to the general requirements set up for aircraft control devices, is applicable also to tank installations. Dynamotor contactor is approx. 2½" wide and 4" high, weighs only 2.3 lbs., can be mounted in any position. It is totally enclosed, with contacts in upper compartment and coil and plunger in lower compartment. Copper-lead-alloy contact tips assure the best high-current inrush performance. Contactor meets Signal Corps vibration requirements, being good for mechanical frequencies of 5 to 55 cycles per second at a maximum of 1/32" amplitude (1/16" total travel) applied in any direction. Single-pole normally-open contacts are designed to stay open when coil is not energized, and closed when coil is en- even when contactor is subjected to a acceleration of 10*G* applied in any tion, or to the vibration conditions above. All ferrous parts are treated sist corrosion. Nonferrous parts are treated except where such treatment interfere with operation. Contactor able for use in ambient temperature ing from 60°C. to −40°C. Contact rat 50 amperes on an 8-hour basis. Inrus rent rating is 500 amperes at 32 volt Coil wattage is 9.5—*Industrial Control General Electric Co., Schenectady, N.*

Multi-point pH Recorder

Simultaneous records of pH at independent points in a fluid-flow system are made available by a new instrument, conventional in appearance but said to incorporate



"an outstanding advance in circuit design that permits installation of the measuring electrodes at separate and independent sampling points in the plant." They are connected electrically to the recorder which may be a "considerable" distance away.—*Cambridge Instrument Co., 3732 Grand Central Terminal, New York City.*

Palmer Thermometers
ARE HELPING
UNCLE SAM

HELP WANTED
UNCLE SAM

Did you know that it requires over 200 Separable-Socket style Thermometers to properly operate ONE U.S. Battleship?

The demand placed on the Thermometer Industry for these requirements alone is heavy but to win this war, we must all co-operate.

To work for Uncle Sam, the thermometers must be strong, they must register quickly and accurately and they must be easy-to-read.

PALMER THERMOMETERS are known for their sturdiness, guaranteed permanent accuracy, their sensitivity and the easy-reading "Red-Reading-Mercury" feature.

LET US HELP YOU WITH YOUR THERMOMETER PROBLEMS

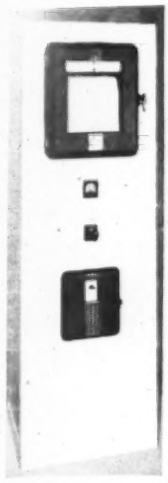
(Catalog No. 300-D sent on request)

THE PALMER CO., Mfrs.

2511 NORWOOD AVE., CINCINNATI, NORWOOD, OHIO
Canadian Plant: King and George Sts., Toronto

Control System for Superheated Steam Temperature

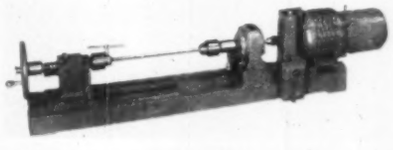
New "Micromax Electric Control" is a control system said to enable steam plants to maintain superheated steam right up to the safe limit, and to hold it there steadily.



New system detects each temperature drift from the control point, and swiftly readjusts damper (or valve) by amount required to return temperature to control point. This primary proportioning action, whereby damper is moved to a definite position corresponding to each temperature value within working range, is not sufficient, for should there be a change in steam demand on boiler unit, new position assumed by damper would result in temperature balancing at some point above or below the control point. To compensate for this discrepancy (called droop) and to return temperature to the control point, the equipment embodies an automatic droop-corrector which detects droop, and shifts relation between measuring circuit and control circuit by a corrective amount. Action is so fast and direct that operating efficiency is bettered and costly equipment protected from damage. A feature is the ease with which operators are said to take over on manual control, then switch back to automatic operation without delay. Also available is a supplementary control for topping units which acts automatically, when load drops off, to prevent exhaust steam temperature from rising excessively and damaging the low-pressure turbine.—*Leeds & Northrup Co., 4934 Stenton Avenue, Philadelphia, Pa.*

Torsion Machine for Wire

New "Model M-39 Torsion Machine," for wire and wire products, has been designed to perform tests rapidly and accurately in accordance with A.S.T.M. specifications.



Gripping heads, consisting of "the finest ball bearing chuck available," are adjustable for convenient positioning of specimen. A three-figure revolution counter registers number of turns required for failure, adds in one direction, subtracts in the other and is quickly reset to zero after each test. Machine consists principally of a motor-driven twisting head and a tailstock for maximum specimen size ¾" in diameter by 16" long, mounted on opposite ends of a cast iron base plate. Rotating gripping chuck, rotating at 13 to 26 r.p.m., is attached directly to output shaft of a direct connected motor-driven universal speed reducer unit. Motor and control illustrated is for two-speed integrally for stopping machine at instant of failure or for stopping before reversing direction of rotation. A single-speed or non-reversing drive can be substituted if desired; and twisting speed can be altered by altering ratio of speed reducer unit.—*Richle Testing Machine Div., American Machine and Metals, Inc., East Moline, Ill.*

A NEW ELECTRIC BOND TESTER

MILLI-OHM-METER MODEL

Ranges 0.5: 0.1: 0.05: 0.01: 0.005: and 0.001 ohms, at full scale

DOES NOT REQUIRE REFERENCE CURVES OR CHARTS . . . THE MEASURED RESISTANCE IS DIRECTLY READ FROM METER SCALE.

The battery-meter and controls are in the case . . . fixed clamp and exploring cables are easily connected.

Send for your copy of Bulletin No. B-16, details and prices are given. These low-resistance testers can be used by non-technical personnel.

HALLCROSS MFG. CO. COLLINGDALE PENNSYLVANIA

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ALL OUT PRODUCTION FOR THE AIRCRAFT INDUSTRY

As suppliers of instruments to the aircraft industry, we are familiar with some of the problems that face you. Our facilities and personnel are available for any additional help required to enable direct or sub-contractors to turn out their products providing our equipment meets requirements.

We are willing to work our machines twenty-four hours a day to turn out the quantities needed by you. This war is one of production and delivery. Keep our air force supplied with essential materials. Let us exceed the Axis production this year, or better yet, this month. Cooperation is necessary and is offered to the extent of our ability.

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Pneumatic Differential Telemetering System

New "Moore Pneumatic Differential Transmitter" has been developed to provide a simple and dependable method of accurately measuring and amplifying small differential pressures and to pneumatically transmit this amplified value to a receiving instrument calibrated in the units measured. Chief characteristic of this method is linearity and constant ratio of amplification. Ratio (varied to suit specific requirements) depends only on a fixed ratio of bellows areas, not on levers or sliding members. Extreme sensitivity is said to be inherent because of the system of pneumatic balance, comparable to electrical "null" method. Differential unit sensitivity is 0.1% of full range; overall installation sensitivity, 0.25%; accuracy within 1%. Differential sealed-in unit is made with phosphor bronze or stainless steel welded bellows according to the application. A separate pilot is provided for long distances. System finds uses in such applications as liquid level, interface level, flow in pipes, ratio flow control, specific gravity, s.g. with temperature compensation, temperature transmission, pressure transmission, etc. *Operation* (see illustrations): Increase or decrease of differential pressure across the large bellows moves it to or from the exhaust nozzle, causing an increase or decrease of the air balancing pressure in the small amplifying bellows. This pressure automatically maintains all the bellows in a position of equilibrium with respect to the exhaust nozzle. This is also the pressure which is transmitted to the remote indicating, recording or controlling instrument.—*Moore Products Co., H & Lycoming Streets, Philadelphia, Pa.*

Switchboard Watthour Meter

New "Type CB" line of switchboard watthour meters is for industrial and central station use. Units are available for metering all the various combinations of single-phase or polyphase power. Mounting styles are flush, projection, also detachable or plug-in models which can be readily removed for overall inspection and test without interrupting the circuit. All calibration adjustments are accessible from front when molded glass cover is removed. CB single-phase meters have one electromagnet; CB meters for the usual 3-wire single-phase circuits have 3-wire current coils; CB-2 meters have two 2-wire elements and may be used on single or 3-phase, 3-wire circuits, and on 2-phase, 3- or 4-wire circuits. CB-3 meters (three 2-wire elements) are used to meter 3-phase, 4-wire star-connected circuits and, when used with instrument transformers, to totalize combined 3-phase, 3-wire and single phase, 2-wire or 3-wire loads. CB-8 meters are of the two-disk type, have two 3-wire electromagnets interconnected to form a 3-current coil meter, are used on 3-phase 4-wire star connected service and are said to be fully accurate wherever the voltages are not extremely unbalanced. CB-10 meters are of the two-disk type, have two separate 3-wire elements, are used on 2-phase, 5-wire service.—*Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.*

Any Questions ABOUT THERMOCOUPLES?

Do you know—

- how to make a thermocouple? See Page 21.*
- where bare thermocouples can, or cannot, be used. See Page 4.*
- what type of protecting tube to use for your application? See Page 14.*
- how to check thermocouples and pyrometers? See Page 22.*

* The above page numbers are from the New Wheelco Thermocouple Data Book and Catalog. Temperature conversion tables, pipe and wire sizes, wire resistances, millivolt tables, decimal equivalents, etc., are also included in this valuable book. Write for your copy TODAY!

Wheelco Instruments Co.
433 HARRISON STREET - - - CHICAGO, ILLINOIS

In ordinary fuses, crystallization and cracking are a common cause of fuse failure, due to repeated expansion and contraction of fuse element. LITTELFUSE Non-Crystallizing Fuse Elements, *efficiently* meet this condition with as much as *six times* the service life of others.

Sizes 1/100 to 8 amps 250 volts. Underwriters Approved

INSTRUMENT LITTELFUSES
and Mountings for Every Requirement

For delicate instruments and other equipment, microammeters, milliammeters, wattmeters, voltmeters, galvanometers, radio, production test equipment, signal meters, thermocouples, battery sets, etc., 1/200 amp. up. Hi-volt 1000, 5000, and 10,000 ranges, 1/16 amp., up. All types of Littelfuses for aircraft, radio, auto, etc., and mountings. Send for complete catalog.

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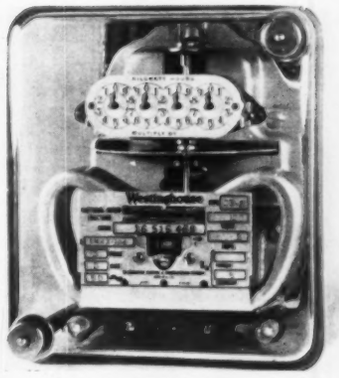
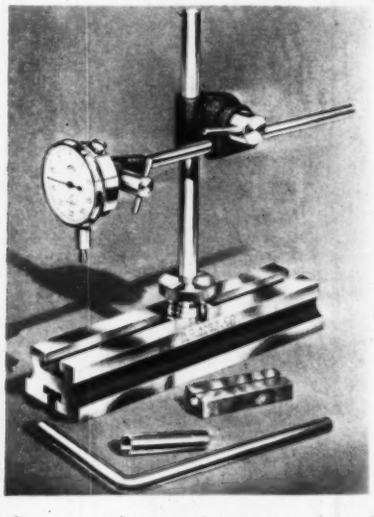


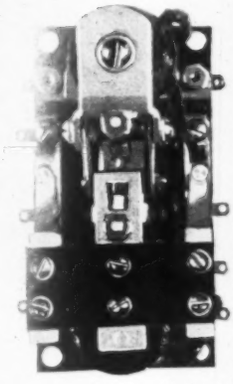
Dial Indicator Assembly

New "No. 22 Dial Test Indicator" is said to be "an ideal testing outfit for machinists, tool-makers, inspectors, scrapers and assemblers," for determining flatness of surfaces, roundness and trueness of revolving parts, relative heights and thicknesses, etc. Instrument is adjustable to any position. Cast iron base 8½" long and 2½" wide is accurately ground top and bottom. Upright rod is ⅝" in diameter and held along the 9/16" top T-slot by an easy turning knurled nut. Horizontal indicator holding rod is ⅝" in diameter and 9" long, adjustable to any position and held securely by a lever style clamp. It can be removed and used in lathes with the tool post clamp shown in illustration. Indicator regularly furnished is maker's No. 202 with ¼" spindle travel, graduated in thousandths and half-thousandths and numbered 0-25-0. Any indicator having a clamping lug or back with ¼" diameter hole can be used. Base Stops are for use in the ⅝" bottom T-slot. Angular base stop is used against dovetail and angular surfaces; plain base stop is used against square surfaces and in T-slots.—*B. C. Ames Co., Waltham, Mass.*



Mechanical Latch-in Electrical Reset Relay

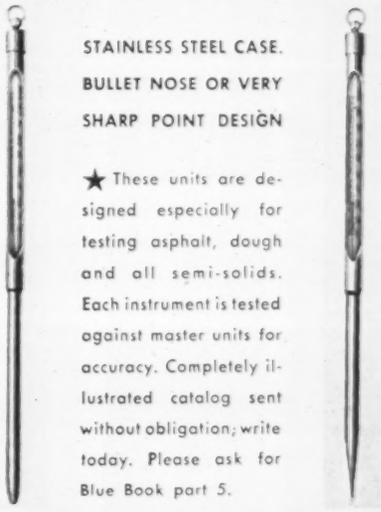
Designed for aviation purposes and to withstand vibration incident to such service, new mechanical latch-in, electrical reset relay, "Type CX3190," operates from a brief impulse without necessity of keeping coils energized. D-p.d-t. contacts are rated at 6 amperes at 12 or 24 volts, d.c. An auxiliary contact breaks one coil circuit. All contacts are insulated from the frame for radio frequency. Coils are for operation on d.c. only. Dimensions of the unit are $3\frac{5}{16}$" high × $1\frac{3}{4}$" wide × $1\frac{3}{8}$" deep. Weight is 7 ounces. Other contact arrangements are also available.—*Struthers Dunn, Inc., 1315 Cherry St., Philadelphia, Pa.*



Conductivity Bridge with Expanded Range

Specific resistance values up to 2.5 megohms, in six ranges, are covered by new "Model RC-1-C" Conductivity Bridge, which is suited to industrial and laboratory measurements. A six-point switch covers the six resistance ranges. A single dial control provides direct resistance readings in conjunction with the multiplying factor of the range switch. Accuracy is guaranteed within 1% except for "extreme ends" of calibration. Accuracy is independent of line-voltage variations. Use of cathode-ray visual null indicator (magic eye) assures ruggedness. Scale length of about 14" (total of 84" over the six ranges) permits close readings. Used as a conductivity bridge in connection with the proper cell, this instrument is said to be sufficiently sensitive to detect impurities in distilled water of the order of 0.5 ppm. of chloride ion. It is said to be equally useful for measurement of highly conductive solutions such as strong acids or alkalis and especially useful for work with very dilute aqueous electrolytes and organic liquids.—*Industrial Instruments, Inc., 156 Culver Ave., Jersey City, N. J.*

ARMORED THERMOMETERS FOR ALL SEMI-SOLIDS



STAINLESS STEEL CASE.
BULLET NOSE OR VERY SHARP POINT DESIGN

★ These units are designed especially for testing asphalt, dough and all semi-solids. Each instrument is tested against master units for accuracy. Completely illustrated catalog sent without obligation; write today. Please ask for Blue Book part 5.

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2525 NO. BROAD ST., PHILADELPHIA, PA.

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★ HERE IS YOUR COMPLETE ★
Source of Supply
for ALL STANDARD
RADIO PARTS
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GREATEST STOCK EVER IN RADIO HISTORY!
CONDENSERS • RESISTORS
TUBES • METERS • TRANSFORMERS
SWITCHES • RELAYS • WIRE
TEST INSTRUMENTS
PLUGS • JACKS • PANELS, etc.
Write us for complete information on any standard nationally-advertised product.

INDUSTRIAL ENGINEERS!
Increase production output!
Factories, aircraft plants, shipyards and government agencies everywhere are now installing amplifier equipment for the dissemination of music to the workers—resulting in 10% to 25% greater output! Also ideal for voicing general instructions, alarms and air raid signals. Write our "SOUND DIVISION" today for full particulars. Address Dept. SS.

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—Established 1922—
TELEPHONE BARCLAY 7-1840

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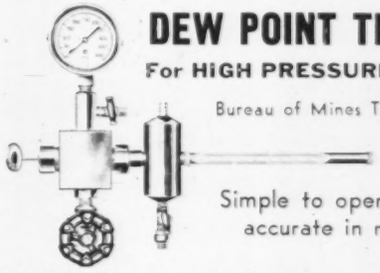

DEW POINT TESTER
For HIGH PRESSURE GASES
Bureau of Mines Type

Simple to operate and accurate in results.

For Working Pressures up to 2500 P.S.I. . . . For Dew-Point Temperatures as low as minus 90° F. . . . Observation made on a sensitive stainless steel mirror. . . . Fully described in catalog 26A.

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SCIENTIFIC LABORATORY AND POWER PLANT EQUIPMENT
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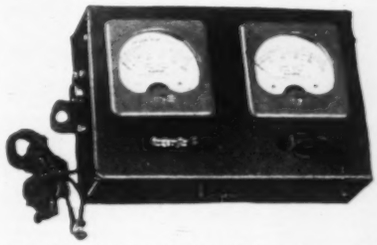


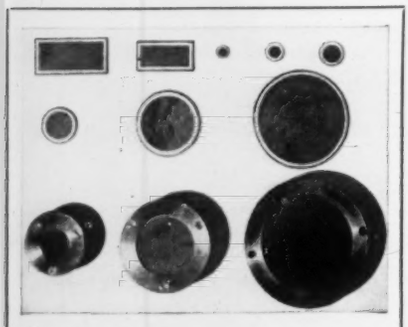
TRU-VAC VACUUM GAUGES
(PIRANI TYPE)

Shown at left is meter box of our model No. 6 gauge.

This gauge successfully used by many of America's foremost manufacturers.

Send for circular on our new low priced D.C. operated gauge.

CONTINENTAL ELECTRIC CO.
GENEVA, ILLINOIS



PHOTOCELLS

(Barrier-Layer Type)

of highest sensitivity

Great variety of sizes and shapes.

Unmounted or mounted in various styles of casings.

Full cooperation regarding application and circuits.

Write for literature

PHOTOVOLT CORP.

95 Madison Ave. New York City

Colorimeters Electronic Timers
Reflectometers Photometers
Fluorescence Meters

Light-weight Aircraft Relay

New "CR2791-A100A" lightweight relay, designed particularly for aircraft applications calling for operation at high altitudes under severe vibration conditions, is also applicable to tank installations. It weighs 4½ ounces, is 3⅛" long, 1⅝" high, and 1⅜" wide, and can be mounted in any position. It is designed for mechanical frequencies of 5 to 55 cycles per second at 1/32" maximum amplitude (1/16" total travel) in any direction. Altitudes from sea level to 40,000 feet and ambient temperature ranging from −40°C. to 93½°C. fall within its performance scope. Balanced-armature construction. Current rating, 25 amp. at 12 or 24 volts. Coil operates at 1.2 watts. Single-pole normally-open contacts are designed to stay open when coil is not energized and closed when coil is energized at rated voltage even when subjected to linear acceleration of 10*G* in any direction, or to the vibration conditions outlined above. Built to meet Army Air Corps specifications, relay is corrosion-proof, having passed, among other rigid tests, Navy's 200-hour salt-spray test.—*Industrial Control Div., General Electric Co., Schenectady, N. Y.*

New Industrial Tubes

Three new industrial tubes—a thyratron, a kenotron, and a phototube sensitive to blue—are announced:

"GL-414" thyratron is an all-metal, negative-grid tube for general-purpose industrial applications said to be characterized by mechanical strength, ease of installation and

low voltage-drop characteristic. Having a shield grid, it is especially suitable for control circuits where available grid power is small and where it is desirable to actuate grid from a high-impedance source. Typical applications: motor controls, welding controls, power rectifiers, voltage regulators, etc. It has an indirectly-heated cathode rated at 5 volts, 20 amperes. Maximum peak inverse anode voltage is 2000 volts, and average anode current is 12.5 amperes.

"GL-451" kenotron is a half-wave rectifier, rated 30,000 volts peak inverse, 500 milliamperes peak, 100 milliamperes average. Its thoriated tungsten filament makes possible a higher rating for size than does a pure tungsten filament. Light weight and a tantalum anode permit construction unaffected by ordinary vibration. This tube is designed to meet high-voltage low-current requirements. It is especially suitable for use with smoke-precipitation and air-cleaning devices.

"GL-441" phototube is especially designed for a high response in the blue region of the spectrum, and has thirty times the quantum efficiency of red-sensitive tubes. Sensitivity is 45 microamperes per lumen at an anode voltage of 90.—*Vacuum Tube Section, E&T Dep't, General Electric Co., Schenectady, N. Y.*

TEST MAGNETIC PROPERTIES OF YOUR STEELS

THE ONLY SINGLE BUTTON ELECTRICAL RETURN FLUXMETER

SIMPLEST AND MOST EFFICIENT
Bulletin 504
THREE DIFFERENT STYLES

Portable Standard with single electrical zero return.

Switchboard Type with above zero feature located on flexible lead for bench operation.

Two Button Pointer Shift in place of our patented standard zero return at a lesser cost.

Acknowledged leaders in development of high sensitivity meters

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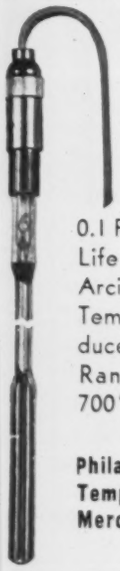
Philadelphia Merc-to-Merc Thermo-Regulators Feature



Mercury to Mercury Contacts : Increased Contact Capacity : Sensitivity within 0.1 F. Exceptionally Long Life and Stability : No Arcing : No Oxidation : Temperature Lag Reduced : Temperature Ranges adjustable to 700°F.

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Philadelphia Merc-to-Merc Temperature Controls and Mercury Plunger Relays

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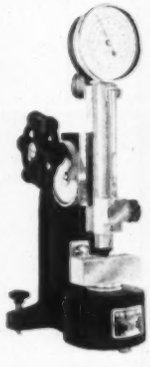
done WITH NO MENTAL HAZARDS. The SCLEROSCOPE has done it for the past 35 years.



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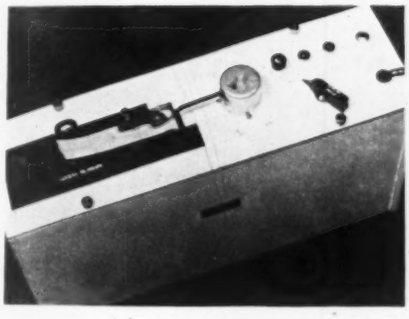

GARCEAU VELOGRAPH

For aeroplane vibration analysis, study of bearing pressures in rotating machinery and seismography, this low-frequency oscillograph is available with up to 20 recording elements. The electrically sensitive recording tape is direct writing, gives a permanent trace. Of rugged design, the Velograph uses no fragile crystals, permanent magnets nor moving coils. Frequency range 0 to approx. 74 cycles per second.

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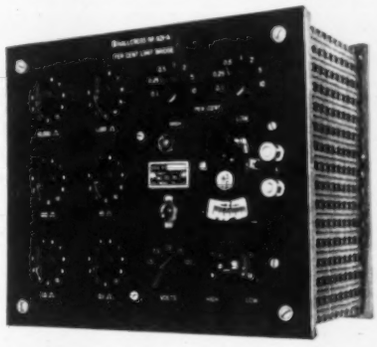
HOLLISTON, MASSACHUSETTS, U. S. A.
Makers of the Garceau Junior Electroencephalograph

Wide-range Bridge for Rapid Production Measurements

New "No. 621-A Percent Limit Bridge" is said to be an exceptionally versatile measuring instrument for rapid and precise production measurement of resistances from one to 1,111,110 ohms. (Other ranges are available.) Outstanding feature is that a selection of tolerance percentages from 0.25% to 10% can be made. "Plus" and



"minus" tolerances may be set individually and independently of each other. Example, the "plus" may be 1% and the "minus" 10%, or vice-versa. Should it be desired to measure actual resistances of units under test, each of the independently-operated percentage dials is set at the "M" position, thereby making bridge instantly ready for use as an ordinary Wheatstone bridge. Working standard may consist of 6 decades totaling 1,111,110 ohms, variable in one-ohm increments, or any other range dictated by user's requirements. New instrument is self-contained. For measuring low resistances there is a standard No. 6 dry cell. For higher resistances, an a-c. operated rectifier tube. Galvanometer sensitivity is one microampere per millimeter division.—*Shallcross Mfg. Co., Collingdale, Pa.*

Insulation Resistance Tester

New "Model 792" Insulation and Cable Covering Resistance Tester is a compact device designed to adapt maker's "Model 785" Industrial Circuit Tester or "Model 772" Test Analyzer for the measurement of insulation resistance up to 900 megohms. New unit fits into compartment of "Model 785" Circuit Tester, and operates from a 100-130-volt 50-60-cycle a-c. supply line. It is connected into the ohmmeter circuit of Models 785 or 772 by means of a pair of leads, and insulation resistance measurement read on the ohmmeter scale. Measurements up to 900 megohms are made at a test potential of 500-volts as recommended by the AIEE, thus making it possible to determine quickly whether insulation properties are above safe working minima. This new tester is now offered as optional equipment with both the Model 785 and 772 test units, and is also offered singly for use with maker's test units now in service and not equipped for insulation testing.—*Weston Electrical Instrument Corp., 591 Frelinghausen Ave., Newark, N. J.*

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Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.

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Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.

Control Drive

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

Recorders for pressure, temperature, drafts, liquid level and other factors.

G-3

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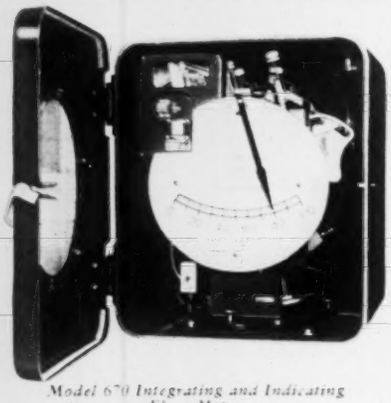

Model 670 Integrating and Indicating Flow Meter

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Standard Differential Range—20" to 150" Water

LOW PRESSURE METERS
Standard Differential Range—1" to 8" of Water

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Range Change Can be Made Without Taking Meter Out of Service

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A high grade instrument for measuring resistances from a fraction of an ohm to 10 megohms. Contains a 4-dial rheostat, ratio dial, galvanometer and battery, all enclosed in a substantial walnut case. Nine coils per dial. Accuracy .1%. Built to endure.

Cat. No. 1050—Portable Wheatstone Bridge with Murray and Varley Loops . . $110.00
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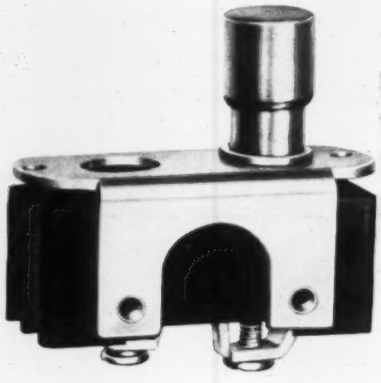
Send for Bulletin No. 105

RUBICON COMPANY
Electrical Instrument Makers
Ridge Ave. at 35th St. Philadelphia, Pa.

Air Corps Type Switch

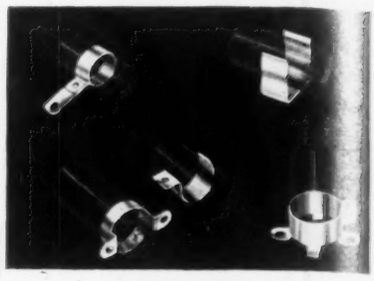
New Air Corps type switch is designed to meet the requirements of U. S. Air Corps specification 94-32249. Assembly consists of a basic "Mu-Switch" with wide contact



spacing mounted in a cadmium-plated steel bracket to which is rigidly attached an over-travel plunger mechanism having a pre-travel of 1 16" minimum and an over-travel of 1/8" ±1/32". Pressure required to operate switch is 1 lb. minimum and 8 lbs. maximum over entire operating range. Electrical rating is 25 amperes at 28 volts d-c., 17 amperes at 125 volts a-c., and 8.5 amperes at 250 volts a-c. non-inductive loads. Wiring connections can be supplied normally-open, normally-closed, and s-p.d-t. Special mounting lugs are provided on bottom to allow use of ring type wire connectors. Construction is superior to old style Air Corps type assemblies wherein over-plunger mechanism was mounted directly on Bakelite switch itself. Now, mechanism is directly attached to steel bracket. Characteristics and dimensions of over-travel plunger mechanism can be changed to adapt new switch assembly to practically any type of application.—*Mu-Switch Corp., Canton, Mass.*

Capacitor Mountings

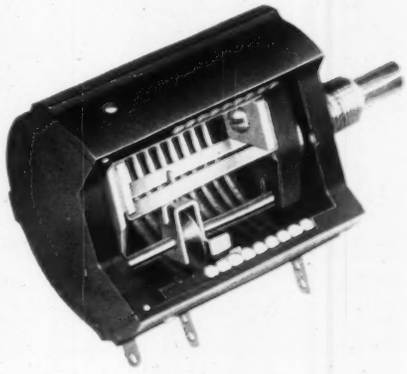
Universal mounting hardware simplifies problem of mounting a capacitor in some position other than that for which its mounting feet, lugs, ring or strap were intended, or securely mounting a capacitor which was designed to be supported by its own wire leads. Stock of capacitors can be limited to simplest types, its variety dictated solely by capacity and voltage values required. Illustration shows a few of the Cornell-Dubilier standard types available through local supply houses, each adaptable to a reasonable variety of capacitor diameters. For diameters beyond this range



larger and smaller mountings are available. These mountings likewise find application with other components. They solve the problem very nicely when it is desired to incorporate flashlight cells for bias purposes in vacuum-tube equipment, for example, holding the cell securely in position yet permitting quick replacement.—*Cornell-Dubilier Electric Corp., South Plainfield, N. J.*

Helical Slide-wire Adjustable Resistor

New Beckman "Helipot" (contraction of "helical potentiometer") is an adjustable resistor in which, instead of a circular resistance wire shaped into a single ring, the



resistance winding has the form of a continuous helix like a machine thread. A simple guide wheel arrangement on slider contact causes slider to follow helical path of wire as knob is rotated. It is said that with this arrangement "*any* length of resistance wire can be coiled into the case without requiring any more panel space than a conventional single-turn unit." Present units are made in one-watt three- and nine-turn models; others can be designed to accommodate almost any desired length of resistance wire. Overall length of present units is approx. 2". "Helipots" can be used in practically all types of electrical instruments, in radios, electronic devices, etc.—*National Technical Laboratories, 820 Mission St., So. Pasadena, Calif.*

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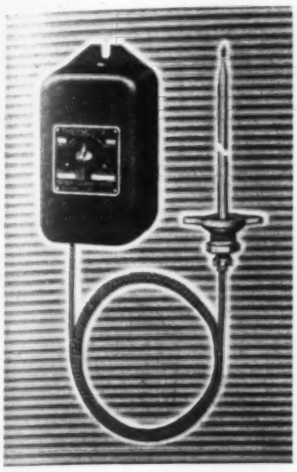

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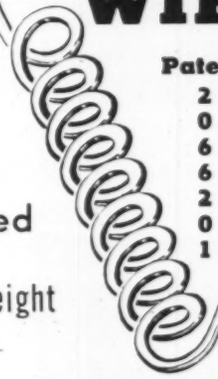
METAL SHIELDED WIRE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